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Resource Analysis for Sustaining Water-Food Security

Proceedings of the Planning-cum-Methodology Workshop organized under National Agricultural Technology Project

Editors

S. Selvarajan
B.C. Roy
N. Suresh

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NATIONAL CENTRE FOR AGRICULTURAL ECONOMICS AND POLICY RESEARCH

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Contents

Acronyms and Abbreviations

µS	Micro siemen
AER	Agro-ecological Region
AESR	Agro-ecological Sub-Region
AICRP	All India Coordinated Research Project
ALAC	Additional Land Available for Cultivation
APWL	Accumulative Potential Water Loss
AWC	Available Water Capacity
BCM	Billion Cubic Metre
$CaCO_3$	Calcium Carbonate
CCA	Culturable Command Area
CEC	Cation Exchange Capacity
CGIAR	Consultative Group on International Agricultural Research
CGWB	Central Ground Water Development Board
cm	Centimetre
$cmol(p^+)kg^{-1}$	Centi mol proton per kilogram
CSSRI	Central Soil Salinity Research Institute
CV	Coefficient of Variation
CWR	Crop Water Requirement
DDP	Desert Development Programme
DPAP	Drought Prone Area Programme
dS/m	Deci Siemens Per metre
EC	Electrical Conductivity
ER	Effective Rainfall
ESP	Exchangeable Sodium Percentage
ESRI	Environment System Research Institute
ET_0	Reference Crop Evapo-transpiration
ET_a	Actual Evapo-transpiration
ET_c	Crop Evapo-transpiration
FAO	Food and Agriculture Organisation
g	Gram
GAU	Gujarat Agricultural University
GCA	Gross Cropped Area
GDP	Gross Domestic Product
GIS	Geographical Information System
GoI	Government of India
GoT	Government of Tamil Nadu
GW	Ground Water
ha	Hectare

ha-m	Hectare metre
I_a	Aridity Index
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
ICMR	Indian Council of Medical Research
ICRISAT	International Crop Research Institute for Semi-Arid Tropics
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IFPSIM	International Food Policy Simulation Model
I_h	Humidity Index
I_m	Moisture Index
IMPACT	International Model for Policy Analysis of Commodities and Trade
INM	Integrated Nutrient Management
IPM	Integrated Pest Management
IR	Irrigation Requirement
IRRI	International Rice Research Institute
IUCN	The World Conservation Union
IWDP	Integrated Watershed Development Programme
IWMI	International Water Management Institute
K_C	Crop Coefficient
kcal	Kilo Calories
kg	Kilogram
LBP	Lower Bhavani Project
LGP	Length of Growing Period
m^3	Cubic metre
m	Metre
M ha	Million hectare
MAST	Mean Annual Soil Temperature
mbgl	Metre Below Ground Water Level
MCM	Million Cubic Metre
me/l	Milli Equivalent per Litre
mg/l	Milligram per Litre
MHM	Million Hectare Metre
mm	Milli metre
MSL	Mean Sea Level
MSP	Minimum Support Price
MSST	Mean Summer Soil Temperature
Mt	Million Tonnes
MWST	Mean Winter Soil Temperature

NATP	National Agricultural Technology Project
NBSSLUP	National Bureau of Soil Survey and Land Use Planning
NCA	National Commission on Agriculture
NCIWRDP	National Commission on Integrated Water Resources Development Plan
NIA	Net Irrigated Area
NSA	Net Sown Area
NSSO	National Sample Survey Organisation
OC	Organic Carbon
P	Precipitation
PAWC	Plant Available Water Capacity
PCI	Per Capita Income
PDI	Provision for Domestic and Industrial Use
PE	Potential Evaporation
PET	Potential Evapotranspiration
pH	Soil reaction
PODIUM	Policy Dialogue Interactive Model
PWD	Public Works Department
ppm	Parts per Million
RDA	Recommended Dietary Allowances
RRPS	Rainfed Rice-based Production System
Rs	Rupees
RSC	Residual Sodium Carbonate
SAR	Sodium Adsorption Ratio
sq km	Square Kilometre
SMCS	Soil Moisture Control Section
SW	Surface Water
SWMP	Soil and Water Management Project
SWOT	Strength Weakness Opportunity Threat
t/ha	Tonnes per hectare
TDS	Total Dissolved Salts
TE	Triennium Ending
TFP	Total Factor Productivity
TLU	Tropical Livestock Unit
TNAU	Tamil Nadu Agricultural University
USAID	United States Aid for International Development
USDA	United States Department of Agriculture
WD	Water Deficit
WRI	World Resources Institute
WS	Water Surplus
WSM	Water Simulation Model
WTCER	Water Technology Centre for Eastern Region

List of Tables

List of Figures

List of Boxes

Foreword

World summit on sustainable development at Johannesburg 2002 declared water as one of the five pillars of providing livelihood without compromising future integrity of resources. Fresh water availability is fixed and increasing population calls upon its most efficient use for production and environmental services. Spatial and temporal variability in water availability is an important concern of equity in its access. Redistribution of rainfall patterns, snow melt, receding glaciers, rise in sea level, changes in perennial river flows, wetlands, water quality, biodiversity and land-use are larger concerns of livelihood gathering. Increasing utilization of groundwater, artificial recharge of depleted aquifiers, recycling of domestic/industrial affluents and aquaculture are unfolding multiple uses of water and resource contaminations.

Water scarcity in some parts and floods elsewhere has become the single greatest threat to food security, human health and natural ecosystems. Finding solutions to water distribution problems reconciling with the goals of economic development and environmental protection require continuous debate among the researchers and policy advocates with the involvement of civil society at large. Satisfying human needs for food, water and economic opportunities while simultaneously maintaining the viability of water-dependent ecosystems and environmental quality shall be the major challenge for this century. Meaningful dialogue on such substantive issues would be possible only if synthesized information on agro-ecological regions is available on continuous basis. This volume is one such attempt to compile the agro-ecological and socio-economic characterization of four AERs for modelling the future water-food security scenarios as a part of the ongoing research project funded by the National Agricultural Technology Project. I compliment the National Centre for Agricultural Economics and Policy Research for bringing out this publication based on the proceedings of the planning-cum-methodology workshop organized by the centre in collaboration with other cooperating centres.

March, 2004
New Delhi

Dr. J.S. Samra
Deputy Director General
Natural Resource Management
Indian Council of Agricultural Research
Krishi Bhawan, New Delhi

Preface

Water and food related issues continue to dominate the national and international agenda of sustainable agriculture development. Challenging goals of food production and agriculture growth will have to be met from the reduced availability of water. Water diverted for agriculture will continue to face rising opportunity costs due to increasing competition from multiple uses. Rising conflicts over water sharing among various users make efficiency enhancement mandatory.

Demand for water will continue to rise while options for augmenting supply are always limited by physical, financial, economic and environmental constraints. Despite all odds, food production growth will have to keep pace with population growth while agriculture sector's growth has to reach 4% per annum matching with the targeted economic growth of 8% during India's X FYP period. This mismatch between the expanding demand for and supply of water emerging and spreading steadily over space and time will have serious implications for meeting the food production growth targets.

A disaggregated understanding of the linkage between water and food by agro-ecological regions will be very helpful for efficient use of water for producing targeted level of production. Our Centre is implementing a research project on Water-Food Security Scenario Analysis for 2025 funded by the National Agricultural Technology Project of ICAR. As per the project design, a planning-cum-methodology workshop on this topic was organized at NCAP. The papers presented and issues highlighted are brought out in this compilation for better understanding of water scarcity and food security related issues in the context of agro-climatic, socio-economic and development-specific characterization of four Agro-ecological regions in India. It is hoped that the publication will be useful. Suggestions on the document are welcome.

March, 2004 — **Dr. Mruthyunjaya**
New Delhi — Director

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This publication is the outcome of a planning-cum-methodology workshop organized on this topic as part of the ongoing study on 'Water-Food Security Scenario Analysis for 2025: Agro-ecological Regional Approach' funded by the National Agricultural Technology Project. We acknowledge NATP for the funding support provided for conducting this workshop. The pioneering work done by the National Bureau of Soil Survey and Land Use Planning in mapping the country into homogeneous agro-ecological zones and sub-zones has provided the basis for pursuing this research project and we gratefully acknowledge their publications as the major source of inspiration and help for the study team.

We thank all the contributing authors from our cooperating Centres namely; Water Technology Centre, Tamil Nadu Agricultural University, Coimbatore; Soil and Water Management Unit, Gujarat Agricultural University, Navsari; Water Technology Centre for Eastern Region, Bhubaneswar and Indian Agricultural Statistics Research Institute, New Delhi for their patience in revising their manuscript several times following their presentation and discussion in the workshop. Dr. Mruthyunjaya, Director, NCAP remained instrumental in conducting this workshop and by guiding us in compiling this publication. We are thankful for the careful English editing done by Dr. B.S. Aggarwal. Last but not least, we acknowledge the sincere efforts of Mr. Adarsh Mohan, Research Associate for his assistance during the initiation of the project up to the workshop.

March, 2004 **Editors**
New Delhi

I. Water-Food Security Scenario Analysis: AER Approach

S. Selvarajan and B.C. Roy

Introduction

India is facing the daunting task of increasing its food production by over 50% in the next two decades. The pressure on natural resource-base has been increasing to meet the growing needs of the society (Table 1.1). For instance, the land and water resource-base for an average farm holding has declined considerably during 1950s through 1990s due to increasing population and diminishing scope for expanding the available natural resource-base.

Table 1.1: Indian agriculture: Increasing pressure on natural resources[1]

Resource	Unit	1950	1960	1970	1980	1990	2000
Net area sown	ha	2.63	2.43	2.05	1.63	1.35	1.12
Gross area sown	ha	2.92	2.78	2.42	2.02	1.76	1.57
Area: fodder/fuel	ha	1.10	0.69	0.51	0.38	0.29	0.22
Net irrigated area	ha	0.46	0.45	0.45	0.45	0.45	0.45
Gross irrigated area	ha	0.50	0.51	0.56	0.58	0.59	0.81
Food grain area	ha	2.16	2.11	1.81	1.48	1.21	1.05
Food grain production	tonne	1.13	1.49	1.58	1.51	1.67	1.95
Food grain yield	tonne	0.52	0.71	0.87	1.02	1.35	1.86

For an average farm holding supporting eight persons

Net and gross areas sown available for an average farm holding have come down to less than half during the past five decades. Based on 2000 population, such an average farm holding has to support eight persons. Land area available to provide fuel and fodder needs for each farm holding has also come down by 80%. Net irrigated area remained constant but gross irrigated area increased by about 66% during this period. With almost 50% reduction in the area under foodgrains per average holding, most of the future agricultural growth will have to come via yield enhancement, that means, more intensive use of natural resources like soil and water.

[1] This table was constructed based on the data from Economic Survey (various years), Ministry of Finance, GoI and Agricultural Statistics at a Glance (various years), Directorate of Economics and Statistics, Ministry of Agriculture, GoI.

Shrinking resource-base on account of quality deterioration is another dimension undermining the future agriculture growth (Table 1.2). Total degraded area has been assessed at 187.7 M ha. Water erosion alone has contributed to 4/5th of the degradation process. Magnitude of degradation is classified as high in more than 2/3rd of the total degraded area. Assuming that agriculture is practiced only in the case of low and medium degraded lands, productivity loss is estimated to be 15 to 33% in these lands. Temporal and spatial spread of degradation process, if not checked and reversed, would threaten India's future food security.

Table 1.2: Soil degradation and productivity loss[2]

Nature of degradation	Magnitude of degradation (per cent of total degraded area)				
	Low	Medium	High	Very High	Total
Water erosion	2.7	12.9	57.1	6.6	79.3
Wind erosion			5.8	1.4	7.2
Salinization & nutrient loss	1.5	1.1	4.7		7.3
Waterlogging	3.4	2.8			6.2
Total	7.6	16.8	67.6	8.0	100
Total area (M ha)	14.2	31.5	127.0	15.1	187.7
Productivity loss (%)	<15%	15-33%	33-67%	>67%	

Water security

Because of the tightening supply and rapid expansion in demand, fresh water is expected to emerge as a key constraint to future agricultural growth. Globally, the demand for water has grown annually by 2.4%. Gross water demand for all uses in India is expected to go up from the current level of 520 BCM (billion cubic metre) in 1997 to 1027 BCM by 2025 (Table 1.3). The gross water demand by irrigation sector alone is estimated to be 730 BCM by 2025, constituting over 70% of total demand. To meet this demand for water, the investment needs are estimated at Rs. 5000 billion.

Then number of countries experiencing water stress is expected to go up from the present 28 (with a total population exceeding 300 million people) to 50 (including India) by 2025 with a total population of 3

[2] Sehgal, J. and I. P. Abrol (1994) *Soil Degradation in India: Status and Impact*, Oxford and IBH, New Delhi.

Table 1.3: Demand for water and investment needs[3]

Purpose	Annual water need in 2000 (BCM)	Gross water demand in 2025 (BCM)	Purpose	Capital need, (Billion Rs.) 2000-25
Irrigation	630	730	Irrigation	1820
Water supply		70	Water supply	1400
Ecology		77	Sewage	1116
Industry	30	120	Sanitation	664
Energy		30		
Domestic/livestock	33			
Thermal power	3			
Miscellaneous	54			
Total	750	1027	Total	5000

billion people.[4] Among the developing countries, India is projected to have the largest absolute increase in water withdrawals between 1995 and 2020. Per capita water availability in India has come down from 5300 (1955) to 1967 m^3 (1997) which is projected to further decrease to 1500 m^3 by 2025 with wide inter-basin variations. During 1995-2020, irrigated area is expected to grow at an average annual rate of 0.7%, far below the growth rate of 1.7% registered during the 1990s[5]. Deceleration has started in irrigation potential created through major and medium schemes during 1980s. Paucity of investible resources due to rising subsidies led to the cutting down in real government expenditure on this sector[6]. Unsustainable physical and financial status of India's water sector has resulted in declining utilization of irrigation infrastructure

3 Rao, P.S. (1999) Draft Report on South Asia Vision for Water, Life and Environment in the 21st Century. South Asia Technical Advisory Committee, Global Water Partnership.

4 Population Action International (1995) *Sustaining Water: An Update*. Population Action International, Washington, D.C and Rosegrant, M.W., C. Ringler and R.V. Gerpacio (1997) Water and Land Resources and Global Food Supply. Paper prepared for the *23rd International Conference of Agricultural Economists on Food Security, Diversification and Resource Management: Refocusing the Role of Agriculture*, held at Sacramento, California, during August 10-16, IFPRI, Washington, D.C.

5 Anderson, Per Pinstrup., Rajul Pandya-Lorch and M.W. Rosegrant (1997) *The World Food Situation: Recent Developments, Emerging Issues and Long-term Prospects.* CGIAR Week, Washington, D.C.

6 Hanumantha Rao, C.H. and Ashok Gulati (1994) *Indian Agriculture: Emerging Perspectives and Policy Issues*. Research paper under USAID Grant No. 386-0282-G-IN-8334, ICAR, New Delhi and IFPRI, Washington, D.C.

created so far. Water resource has become vital for economic growth and sustainable development. As water becomes increasingly scarce, conflicts are rising between nations, states, districts (Box 1.1) as well as groups (Box 1.2) over sharing of this critical resource.

Box 1.1: Water wars
(Eurasia Times, August, 2003)

Increasing water-related conflicts involving states have resulted in inter-district water wars as witnessed in Andhra Pradesh recently. Rajolibanda project in Raichur district of Karnataka regulates the flow of Tungabhadra river water into Kurnool and Mahabubnagar districts of Andhra Pradesh. Several farmers of these two neighbouring districts of Andhra Pradesh state physically clashed to prevent each other from accessing the waters of Tungabhadra River for irrigation purpose, leaving many of them seriously injured. The fight over controlling the sluice gates of Rajolibanda project forcibly to regulate the water flow into one district over the other has reached a flash point due to increasing scarcity of water in this drought-prone region.

Demands on water sector, from both surface and ground water sources, are accelerating with population growth and development, and with competition from multiple users (Table 1.4).

Water scarcity can be defined either in terms of the existing and potential supply of water, or the present and future demands/needs for water, or both. One of the pioneering studies of water scarcity[7] adopted a supply-

Table 1.4: Projected expansion in water demand by uses[8]

(BCM)

Uses/Sources	1990	2000	2025
Irrigation purpose	460	630	770
Domestic needs	25	35	52
Energy needs	19	27	71
Industrial demand	15	30	120
Other uses	33	30	37
Total demand	552	750	1050
Surface water sources	362	500	700
Ground water sources	190	250	350

[7] Falkenmark, M. and C. Widstrandt (1992) *Population and Water Resources: A Delicate Balance.* Population Bulletin 47 (3), Population Reference Bureau, Washington, D.C.

[8] Rao, R. Vidyasagar (1993) *Water and Sustainable Development: Indian Scenario*, United Nations Publication, ISBN 92-1-119826-7.

side approach by using the per capita amount of annual water resources to rank water scarcity prone countries. They defined 1700 m^3 per capita per year as the level of water supply above which shortages will be local and rare. Total annual renewable fresh water available in India has been assessed at 2085 BCM. Annual per capita water availability is falling and is expected to go below the water-scarce threshold level of 1700 m^3 within the next two decades. Besides temporal variability in water needs and supply, spatial variability adds another dimension towards the status and sustainable use of water. For instance, Brahmaputra basin, accounting for only 6% of the country's area, holds 29% of the country's water resources. In some parts of the western and southern regions, water availability is as low as one-fourth of the national average.

Box 1.2: Peasant protest against diversion of water resources (Muzaffar Assadi, 1999)

Karnataka government constructed a 10-km long tunnel, 200-feet below the ground level during 1979-94 from Bagur-Naville in Channarayapatna in Hassan district to Tumkur city for diverting the water to meet the increasing demands for water. This diversion had negative externalities on the rural agriculture households, affecting more than 40 villages between Bagur and Naville. Water level started falling, wells got dried up, and plantation economy got crippled over years. Rural poverty in these villages intensified. Peasants of the affected villages organized series of agitations asserting their rights over sharing of water. The struggle led to 96-day sit in strike during 1998 along the tunnel, blocking the flow of water by the men while women organized hunger strike to collectively assert their loss of rights over water. Competition for multiple uses of water is intensifying with increasing scarcity of available water resources and rural-urban conflicts over domestic and agriculture uses of water are emerging in more regions.

Development and utilization of groundwater gained momentum with the innovation of individual farm-owned pumpset technologies and rapid expansion of electrification aided by increasing flow of institutional credit starting from 1970s. The spread of groundwater development beyond the green revolution areas continued during 1980s and 1990s. Lack of comprehensive policies to guide ground-water development and use in a sustainable manner resulted in over-exploitation of this resource in varying magnitudes at several locations. The symptoms are spreading (Table 1.5). In 1995, more than 50% of the dark blocks were located in six states, namely Gujarat, Haryana, Punjab, Tamil Nadu, Karnataka and Rajasthan. These states, together, accounted for 88% of the over-exploited blocks. Again, in these states alone, number of blocks exploiting more than 85%

(dark and over exploited category) of the utilizable groundwater resources has gone up by more than 100% within a period of about five year during 1990s. The magnitude and spread of over exploited blocks in mid-1990s signal the disturbing trends emerging in India's water sector, warranting comprehensive water policies encompassing all uses and sources of water.

Table 1.5: Spatial and temporal status of ground water exploitation in selected states[9]

States	Ground water statistics, 1989			Ground water statistics, 1995		
	Total blocks	Grey blocks	Dark blocks	Total blocks	Over exploited	Dark blocks
Gujarat	183	13	6	184	13	15
Haryana	95	11	31	108	45	6
Karnataka	175	9	3	175	6	12
Punjab	118	18	64	118	72	11
Rajasthan	227	12	21	236	74	20
Tamil Nadu	375	66	61	384	64	39
India	3841	339	281	5711[@]	310	160

[@] This includes blocks/mandals/watersheds/taluks/ for all the states. Blocks are categorised, based on the exploitation of utilisable groundwater resources, as grey (65 to 85%); dark (85 to 100%) and over exploited (more than 100%).

Irrigation-led growth in agricultural sector aided by intensive use of fertilizers and pesticides has led to inter-spatial and inter-temporal externalities in the intensive agriculture zones of India. Fertilizer and pesticide chemicals use is skewed across crops and regions; much lower in magnitude at aggregate level in large parts yet; but eutrophication of lake and river water bodies, nitrate pollution of ground water, increased emission of gaseous, nitrogen and metal toxicities are the environmental externalities emerging now. Highest pesticide use exceeding one kg per ha is reported in Andhra Pradesh, which is again concentrated in cotton and paddy areas. Along with Andhra Pradesh, Haryana, Punjab and Tamil Nadu states accounted for more than two-fifth of the pesticides used in the country. Externalities associated with the over-use of pesticides to control cotton bollworm in Andhra Pradesh are already witnessed in the form of increased resistance to pesticides. The presence of pesticide residuals far exceeding the tolerance limits in the case of milk, canned fruit products, poultry feeds and vegetables has been revealed by some studies.

9 CGWB (1989) *Ground water statistics*, Ministry of Irrigation and Power, Department of Irrigation, GoI, New Delhi and CGWB (1985) *Groundwater Resources of India,* CGWB, Ministry of Water Resources, GoI, Faridabad

Natural resource and environment related issues are coming to the forefront and getting internalised into the agricultural technology management process. But the pace is not matching with the increasing complexity of the inter-linkages between agriculture growth and environment. For instance, major shift towards aquaculture in different parts of the country with about 60000 ha of paddy fields in Andhra Pradesh getting converted into fish culture coupled with mushrooming growth of brackish water prawn culture in the coastal region could not be sustained for long due to its adverse ecological implications. Alternative pathways for sustainable development in agriculture sector need to be evaluated for searching right solutions but yet to be attempted.

In six of the country's 20 major river basins (with less than 1000 cubic meter of annual per capita availability), water resources are under stress and depleting. By the year 2025, five more basins will become water scarce and by 2050, only three basins in India will remain water sufficient[10] . Because of tightening supply and rapid expansion in demand, water security is expected to emerge as a key constraint for future agricultural growth. In Gujarat, over-pumping from coastal aquifers resulted in rapid expansion of agricultural production in 1960s through 1970s. But with the salt water intruding into fresh water aquifers, productivity advantage realized earlier has collapsed as quickly as it expanded[11] . Similarly, in many regions across the country, groundwater tables have been falling at an average rate of 2 to 3 m per annum as the well irrigation intensity grows. Such alarmingly depleting ground water levels in many parts of the country is expected to put at least 25% of the country's future harvest at risk. As competition for limited water supply increases, responding effectively to these demands is a continuous challenge requiring comprehensive understanding of emerging scenario in water sector differentiated by agro-ecological regions.

Food security

With continuous growth in population, agricultural growth has to strike a balance between three needs: (i) to provide food and nutrition security to the country, (ii) to accelerate income growth to alleviate poverty and

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[10] Indian Water Resources Society (1997) *River Basin Management: Issues and options,* Paper for Water Resources Day, Indian Water Resources Society.

[11] Molden, David., Upali Amarasinghe and Intizar Hussain (2001) *Water for Rural Development* Background paper prepared for the World Bank. Working Paper 32. IWMI,Colombo, Sri Lanka

(iii) to quicken the pace of economic growth. For instance, the latest estimations on cereal supply and demand in India to 2020 have revealed cereals shortages of different magnitudes under varying per capita income (PCI) growths and supply-related assumptions (Table 1.6).

Table 1.6: Projected cereals shortages for India in 2020[12]

Supply scenario	Total net supply, Mt	Demand for food & feed		
		PCI growth		
		2%	3.7%	6%
Total demand, Mt		257	296	375
		Cereals shortage, Mt		
Based on historical trend (1965-93)	321	64	25	-54
Increased nutrient & irrigation use	232	-25	-64	-143
Plus improved genetic/technical efficiency	260	3	-36	-115

Another study has projected surplus cereals supply over the demand by 2025 (Table 1.7) with a per capita income growth of 5% per annum. Even with decelerating growth in total factor productivity (TFP), no shortage in cereals is observed. Wide divergence among these estimates is due to differing expenditure elasticity used in respect of cereals, meat, egg, milk and milk products by the two studies.

Yet, another study[13] by IFPRI has projected a cereal shortage of 18 million tonnes in 2025 under 'business as usual scenario'.

Improving the use-efficiency of existing resources like land, water, fertilizer, infrastructure, etc. will be crucial to relax the supply side constraints on future agricultural growth and food security. The role of irrigation water will remain crucial in the whole process of sustaining future food security in view of its complementarity with other yield enhancing and/or cost-saving inputs. Irrigation, therefore, retains its catalytic role in productivity-led future agricultural production growth, in ensuring India's food security and alleviating poverty and malnutrition.

[12] Bhalla, G.S., Peter Hazell and John Kerr (1999) *Prospects for India's Cereal Supply and Demand to 2020.* Food, Agriculture, and the Environment. Discussion Paper 29, IFPRI, Washington, D.C.

[13] Rosegrant, M.W., Ximing Cai and Sarah A. Cline (2002) *World Water and Food to 2025: Dealing with scarcity.* IFPRI, Washington, D.C.

Table 1.7: Projected cereals demand and supply for India in 2020[14]

(Mt)

Year	Supply	Demand	Gap
	Constant growth in TFP assumed		
1995	173	167	6
2020	309	266	43
	Decelerating growth in TFP assumed		
1995	172	167	5
2020	271	266	5

Regionalization Experiences

Identifying agriculturally homogeneous regions based on pre-defined criteria is useful and any planning should attempt at optimum development of such regions subject to capability, which could be enhanced by investment in resource development. The approach should match resources with production systems under varying technologies and formulate scenarios of agricultural output frontiers and status of natural resources. The natural resource management should strive for maximum efficiency through extensive and intensive use along with sustainability with emphasis on regionally differentiated strategies. Regional approach facilitates in planning of resource endowments on a spatial premise and developing area plans covering optimal agricultural activity-mix. Sectoral planning addresses individual items in a schematic form rarely taking into account the natural resources available, their criticalities and use. The problems of land degradation, depletion of groundwater, unsustainable use of canal waters, water congestion, depleting crop productivity, etc., could be examined in depth by each region and strategies suggested along with investment implications and benefits. Realizing the importance of regional planning strategies, several attempts have been made to shift from sectoral approach of planning to resource based regional planning for sounder agriculture development. The overall goal in the water-food security scenario analysis is to evaluate alternative plans based on the potentials and priorities of the regions, broadly homogeneous in terms of land and water resources. One of the existing regionalization approaches will have to be considered for their suitability for the present exercise.

[14] Kumar, P. (1998) *Food Demand and Supply Projections for India,* Agricultural Economics Policy Paper 98-01, IARI, New Delhi.

Agro-ecological Regions

Several classifications/zonifications of the country are available[15] for targeting agricultural research infrastructure development (NARP); focusing on agricultural research and adoption domains (ICRISAT); identifying suitable cropping patterns (NCA); formulating regionally differentiated development strategies (ARPU/PC); sustainable rainfed agricultural development (ICAR/ICRISAT); or for identifying potential agricultural land-use options without adversely affecting the natural resource-base (NBSSLUP). Since biophysical features would drive the availability and utilization of water, agro-ecological regional approach evolved by NBSSLUP on the basis of bio-climates, physiography, etc, provides the basis for studying the water-food security issues at a more disaggregated level, which can be scaled up to the country level. Such an approach would facilitate both regional and national level planning that can complement to promote sustainable water and food security in the country.

Several studies have been focusing on the issues related to India's food security and food demand projections and water security issues in the future. But, the linkages between water and food security aspects at disaggregated levels have not been addressed in the country level studies. Issues like, what would be the matching irrigation infrastructure development and what are the implications for future water as well as food security for different food projection levels or shifts in consumption pattern or magnitudes of income growth, cannot be understood unless the food-water security linkage is studied. Available knowledge in this area[16] is at the aggregate country level, which is justifiable for global level assessment but more disaggregated level knowledge, by agro-ecological regions within India will be much more relevant for meaningful planning, which is currently lacking.

Water security has become a critical constraint to food security in many developing countries, including India and understanding their linkage, differentiated by agro-ecological region, is necessary[17]. Stiff competition

[15] Basu, D.N. and S.P. Kashyap (1996) Agro-Climatic Regional Planning in India. Concept Publishing Company, New Delhi.

[16] Seckler, David, Upali Amarasinghe, Molden David, Radhika de Silva, and Randolph Barker. 1998. *World Water Demand and Supply, 1990 to 2025: Scenarios and Issues*. Research Report 19, IWMI, Colombo, Sri Lanka

[17] The capacity of India and China to efficiently develop and manage water resources, especially on a regional basis, is likely to be one of the key determinants of global food security, as we enter the next century (David Seckler et al., 1998)

has been developing between different uses and users of water. Increasing irrigation water constraint makes policy designing more complex, to meet the food demand, which is changing with varied growth in population, income and consumption pattern. Scenario testing and sensitivity analysis in an explorative framework will be useful to determine the increasing water demand in future as a result of population growth and changing diets. Several useful studies, available at the aggregate level in water and food sectors independently[18] have generally adopted either a supply side or demand side approach. Integrated approach by simulating the demand for water to meet the future food-security needs in an interactive mode will help in analyzing water availability and food production scenarios for future. Such an exploratory modelling application by agro-climatic regions will capture technical, social and economic interactions and trade-offs within the AER, further differentiated by AESRs.

Available models like Policy Dialogue Model[19] and International Model for Policy Analysis of Commodities and Trade[20] at global or country level provide more opportunities now for necessary adaptation and application differentiated by agro-ecological regions within the country.

The Water-Food 2025 Project

The Water-Food 2025 Project[21], through a suitable analytical framework, will develop alternative scenarios of water-food security by agro-ecological regions in tune with India Water Vision 2025. Such an analytical

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[18] Radhakrishna, R. and C. Ravi (1994) *Food Demand in India: Emerging Trends and Perspectives.* Mimeo. Centre for Economic and Social Studies, Hyderabad, India; Kumar, P. (1998) *Food demand and supply projections for India*. Agricultural Economics Policy Paper 98-01. IARI, New Delhi: IARI; Bhalla, G.S., Peter Hazell and John Kerr (1999) *Prospects for India's Cereal Supply and Demand to 2020.* Food, Agriculture, and the Environment Discussion Paper 29. IFPRI, Washington, D.C.; and Institute for Human Development (2000) *India Water Vision 2025.* Report of the Vision Development Consultation, India Water Partnership, Institute for Human Development.

[19] IWMI (2000) *World Water Supply and Demand.* IWMI, Colombo, Sri Lanka.

[20] Rosegrant, M.W., Siet Meijer and Sarah A. Cline (2002) International *Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT): Model Description,* IFPRI, Washington, D.C.

[21] Water–Food Security Scenario Analysis for 2025: Agro-Ecological Regional Approach, National Agricultural Technology Project approved under Competitive Grants Programme, 2001

framework can be extended to assess the trade-offs between agro-ecological goals at regional level and attainable socio-economic options at farm household level.

The World Water Vision recognizes the rate of expansion of irrigated agriculture as the key uncertainty in world's water future. Water as a source of irrigation has emerged as the mainstay of the food-agricultural economy. Water security is emerging as a critical constraint to food security in many developing countries, including India. Some experts predict that uncontrolled depletion of groundwater may well put 25% of India's harvest at risk. Future food security, therefore, depends on the sustainable management of water resources for irrigation. The consequences of not addressing this problem would be catastrophic, especially for the poor, who are most affected by water scarcity. Some of the options being debated either singly or in combination to achieve water-food security and expanding irrigation at faster rates, enhancing yield in either rainfed agriculture or existing irrigation or both, small scale approaches in agriculture, more in harmony with nature. All these require a technically sound information base on water-food security related linkages extending into future. Understanding the future scenario in respect of water-food security would facilitate the planners and policy makers to devise strategies for achieving both, without staking future environmental needs.

The overall goal is to strengthen the knowledge-base and develop exploratory models as a tool for policy makers, scientists and others to interact and address sustainable water-food security related issues in an integrated framework at national and regional levels. Specific objectives are:

- To formulate an integrated policy interactive dialogue model for simulating alternative scenarios of water-food security for 2025 and

- To explore the technical, social and economic aspects of alternative visions of the future water-food security differentiated by agro-ecological regions

The spatial coverage of the study will be four agroecological regions of the country (Table 1.8). These AERs were selected based on the sustainable livelihood security index (Saleth, 1993) developed for 80 sub-agroclimatic regions of the country. This index integrates ecological, economic and equity aspects which are central to the water and food security status for any region. Selected four AERs cover 14 states. In the selected 14 states, dominating states were Uttar Pradesh, Rajasthan, Orissa, Tamil Nadu, Bihar, Haryana, Madhya Pradesh and Gujarat which together account for more than 80% of the selected districts. Some of the targeted states in the study like Gujarat, Haryana, Karnataka, Punjab, Rajasthan and Tamil Nadu alone accounted for three-fourths of the total dark and over-exploited blocks in the country (as on 1995). Again in these states, the number of dark and over-exploited blocks has increased by 71 per cent during the period 1989-95, highlighting the unsustainable trends in groundwater sector.

Table. 1.8: Water-Food 2025-Project Coverage

AER	AESR	Districts	States (number of districts covered)
2	2.1	5	Rajasthan (5)
	2.2	1	Gujarat (1)
	2.3	14	Gujarat (1), Haryana (4), Punjab (2), Rajasthan (7)
	2.4	3	Gujarat (3)
4	4.1	33	Haryana (10), Punjab (6), Rajasthan (6), Uttar Pradesh (11)
	4.2	13	Gujarat (5), Rajasthan (8)
	4.3	17	Madhya Pradesh (1), Uttar Pradesh (16)
	4.4	8	Madhya Pradesh (4), Uttar Pradesh (4)
8	8.1	7	Tamil Nadu (7)
	8.2	10	Karnataka (10)
	8.3	14	Andhra Pradesh (1), Tamil Nadu (13)
12	12.1	12	Andhra Pradesh (1), Maharashtra (2), Chattisgarh (1), Orissa (8)
	12.2	6	Andhra Pradesh (2), Orissa (4)
	12.3	13	Jharkhand (8), Orissa (1), West Bengal (4)
Four AERs	14 AESRs	156 Districts	14 States; Rajasthan (26), Gujarat (10), Haryana (14), Punjab (8) Uttar Pradesh (31), Madhya Pradesh (5), Tamil Nadu (20), Karnataka (10), Andhra Pradesh (4), Orissa (13), Chattisgarh (1), Jharkhand (8), Maharashtra (2) and West Bengal (4)

This project is being implemented in collaboration with many institutions drawn from National Agricultural Research System with each covering specific agro-ecological and/or sub-agroecological regions falling within its domain (Table 1.9).

Table 1.9: Collaborating centres and scientists

AER	AESR	Districts	Collaborating centres	Collaborating scientists	Specialization
2	Four	23	Gujarat Agricultural University, Navsari	S. Raman, CCPI	Soil and Water Management
				R.G. Patil	Soil Science
4	Four	71	National Centre for Agricultural Economics and Policy Research, New Delhi (Lead Institute)	S. Selvarajan, PI	Natural Resource Economics
				B.C. Roy, CCPI	Natural Resource Economics
			Indian Agricultural Statistics Research Institute, New Delhi	D.R. Singh	Economics
8	Three	31	Tamil Nadu Agricultural University, Coimbatore	K. Palanisami, CCPI	Water Resource Economics
				N. Asokaraja	Agronomy
12	Three	31	Water Technology Centre for Eastern Region, Bhubaneswar	H.N. Verma, CCPI	Irrigation Engineering
				P. Nanda	Water Resource Economics
				R.B. Singandhupe	Agronomy
				Gouranga Kar	Meteorology
				D. Panda	Agricultural Statistics

A methodology-cum-planning workshop was organized during the initial stages of the project period to present and discuss the agro-biological, biophysical and socio-economic characterization of the selected four agro-ecological regions encompassing 14 agro-ecological sub-regions. The Lead Centre presented the proposed project framework followed by a comprehensive methodology review covering supply-demand for food and water studies from the literature for discussing and deciding the methodological approach for the proposed Water-Food 2025 project. Each of the cooperating centers presented the agro-biological and socioeconomic characteristics of the selected AERs. Following chapters document[22] the project framework, characterization of selected AERs/ AESRs and the methodology for water-food security scenario analysis evolved during the workshop deliberations.

[22] The write-ups presented here are the substantially revised versions of the papers presented during the Workshop.

II. Resource Analysis for Sustainable Agriculture Development in AER 2

S. Raman, S.L. Pawar, J.M. Patel and R.G. Patil

Introduction

Based on the agro-climatic conditions, five different agro-ecosystems have been identified in the country viz., Arid, Semi Arid, Sub Humid, Humid, Per Humid and Coastal and Island. On the basis of mean annual temperature, the arid system has been sub-divided into cold arid and hot arid eco-systems and 20 Agro-ecological regions (AERs). While the former, with the mean annual temperature of less than 8 ^{0}C is confined to the Himalayan region, the latter with the mean annual temperature of more than 22 ^{0}C, is spread mainly in the states of Rajasthan, Gujarat and Haryana and to a lesser extent in the states of Punjab, Karnataka and Andhra Pradesh. The arid systems existing in the northern and western India are characterized as Western Plains Hot Arid Ecosystem, the system in the Deccan area is classified as Deccan Plateau Hot Arid Ecosystem. Depending upon the moisture index, the hot arid system has been further classified into hyper arid, where the moisture index is less than -83.2 with the Length of Growing Period (LGP) less than 60 days, and typic arid where the moisture index is between –66.7 and –83.2 with LGP between 60 and 90 days. The western plains hot arid ecosystem that falls under AER 2 is sub-divided into four Agro-ecological sub-regions, namely AESR 2.1, 2.2, 2.3 and 2.4 (Table 2.1).

Climate

AESR 2.1

The mean annual precipitation (P) in AESR 2.1 is 294 mm, ranging from a minimum of 179 mm to a maximum of 366 mm in different districts. Monsoon starts from late June and extends up to September. Out of the total rainfall, the monsoon rainfall contributes to 84 per cent. In all other months, rainfall is less than 10 mm. As against this, the potential evaporation (PE) ranges between 1662 and 2064 mm (Table 2.2). The precipitation is only 9 to 20 per cent of the evaporation. During all the months of the year, PE always exceeds P (Fig. 2.1). The mean monthly evaporation is around 150 mm. The mean daily evaporation is 2 to 3 mm

Table 2.1: Extent of coverage of AER 2

Particulars	AESR 2.1	AESR 2.2	AESR 2.3	AESR 2.4
Nomenclature	Marusthali hot, hyper-arid eco-sub-region	Kutch Peninsula (Great Rann of Kutch as inclusion), hyper-arid eco-subregion	Rajasthan Bagar, North Gujarat plain and South-western Punjab plain, hot, typic-arid, eco-subregion	South Kutch and North Kathiawar Peninsula, hot typic-arid eco-subregion.
Extent	12.5 M ha; 3.7% of the geographical area of the country and 38.5% of AER 2	Small sub-region covering 2 M ha; 6.2% of eco-region and 0.6% of geographical area of the country	13.7 M ha; 3.4% of geographical area of the country and 36% of AER 2	6.9 M ha; 1.8% of geographical area of the country and 19.1% of AER 2
Distribution	Barmer, Bikaner, Jaisalmer, major parts of Jodhpur district (West arid zone) and western and central parts of Ganganagar (North arid zone), districts of Rajasthan; and southern tips of Firozepur district of Punjab	Northern part of Kutch Peninsula comprising Lakhpat, Banni and Great Rann of Kutch	Bhiwani, Hissar, Mahendragarh, Rewari and Sirsa districts of Haryana; Bathinda and south central parts of Faridkot and southern parts of Firozpur districts of Punjab; Pali, Sirohi, Jalore, Sikar, Nagaur, Jhunjhunu, Churu and eastern half of Jodhpur and eastern fringe of Ganganagar districts of Rajasthan; and Banaskantha, western Mehsana and parts of Surendranagar districts of Gujarat	Kutch, Jamnagar, northern part of Rajkot and western and north western Surendranagar districts of Gujarat

Table 2.2: Climatic water balance of AESR 2.1

(mm)

Variables	Barmer	Bikaner	Jaisalmer	Ganganagar	Jodhpur
Precipitation (P)	314	306	179	303	366
Potential evaporation (PE)	1857	1771	2064	1662	1842
P– PE	–1543	–1465	–1886	–1359	–1476
Storage	0	0	0	0	0
Actual Evapotranspiration (ET_a)	314	306	179	303	366
Water deficit (WD)	1543	1465	1886	1359	1476
Water surplus (WS)	0	0	0	0	0
Accumulative potential water loss (APWL)	–8462	–8940	–11506	–8951	–7831
Available water capacity (AWC)	150	50	50	50	100
Humidity index (I_h), %	0	0	0	0	0
Aridity index (I_a), %	83.1	82.7	91.4	81.8	80.1
Moisture index (I_m), %	–83.1	–82.7	–91.4	–81.8	–80.1

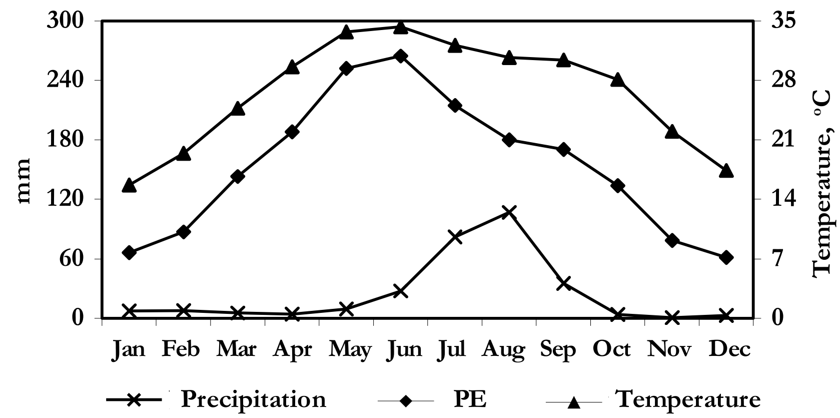

Figure 2.1: Climatic water balance for AESR 2.1

during winter, rising to 6 to 8 mm during summer and around 5 to 6 mm during monsoon season (Table 2.4). Due to the sandy nature of the soil and less intensity of rainfall, run-off is very small and therefore effective rainfall is normally 90%. During the non-monsoon months, effective rainfall is 100% and during the monsoons it is between 85 and 90%.

The difference between P and PE is highly negative, varying between 1359 and 1885 mm. The water deficit is also very high and equals P–PE values. The hyper-arid condition is revealed by the aridity index which is between 80 and 90%. The monthly mean temperatures indicate hot summer and very cold winter conditions. This sub-region is characterized by strong westerly winds during summer, resulting in sand storms and sand movements. These sand movements bring about the dune formation of varying sizes as well as surface creeping.

AESR 2.2

Climatically this sub-region is hot hyper-arid with hot summer and cold winter. During summer, the mean maximum temperature rises to 40 ^{0}C. In winter, the mean minimum temperature goes down to 10 ^{0}C. The mean annual rainfall is 293 mm (Table 2.3).

The monsoon breaks open during the third week of June and extends till first fortnight of September and 97% of the rainfall is received during south-west monsoon, which is very erratic with a high coefficient of variation (CV) of more than 90%. During rest of the months, mean

Table 2.3: Climatic water balance of AESR 2.2

(mm)

Particulars	Value
Precipitation (P)	293
Potential evaporation (PE)	1988
P–PE	–1695
Storage	74
Actual Evapotranspiration (AET)	396
Water deficit (WD)	1591
Water surplus (WS)	0
Accumulative potential water loss (APWL)	–9452
Available water capacity (AWC)	100
Humidity index (I_h), %	0
Aridity index (I_a), %	80.1
Moisture index (I_m), %	–80.1

monthly rainfall varies between zero in the month of May and 3.3 mm in February. The probability of getting annual rainfall of more than 300 mm is 53%. Mean annual effective rainfall is 82% of the total rainfall. Between November and May, it is 100%, while during July and August it is around 80% and 92 to 94% in the months of June and September. The mean annual evaporation is 1988 mm and precipitation is hardly 15% of the total annual evaporation. The potential evapotranspiration (PET) is always more than the precipitation during any part of the year, including the main monsoon months of July and August (Fig. 2.2).

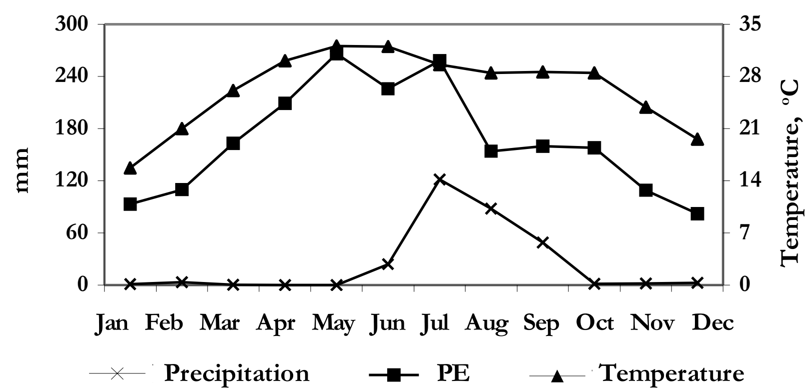

Figure 2.2: Climatic water balance for AESR 2.2

Table 2.4: Mean monthly climatic water balance of AESR 2.1

(mm)

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Precipitation (P)	7.4	7.9	5.4	4.5	9.5	27.5	82.0	106.8	35.1	3.8	0.8	2.7	294
Potential evaporation (PE)	66.4	87.0	143.0	188.0	251.8	264.4	214.8	179.8	170.2	133.8	78.6	61.4	1839
Temperature (°C)	15.7	19.4	24.7	29.6	33.7	34.3	32.1	30.7	30.4	28.1	22	17.4	26.5*
Effective rainfall (%)	100	100	100	0	0	0	0	0	98	100	100	100	99
Potential evaporation (mm/day)	2.2	2.9	4.8	6.3	8.4	8.8	7.2	6.0	5.7	4.5	2.6	2.0	5.0

*Annual mean value

Table 2.5: Mean monthly climatic water balance of AESR 2.2

(mm)

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Precipitation (P)	1.0	3.3	0.2	0.1	0.0	24.2	121.5	88.0	49.0	1.3	2.0	2.4	293
Potential evaporation (PE)	93.0	110.0	163.0	209.0	266.0	226.0	258.0	154.0	160.0	158.0	109.0	82.0	1988
Temperature (°C)	15.7	21.0	26.1	30.1	32.1	32.0	29.6	28.5	28.6	28.5	23.9	19.6	26.3*
Effective rainfall (%)	100	100	100	100	99	96	74	85	94	99	100	100	82
Potential evaporation (mm/day)	3.1	3.7	5.4	7.0	8.9	7.5	8.6	5.1	5.3	5.3	3.6	2.7	5.4

*Annual mean value

The mean daily evaporation varies from 2.7 mm in the month of December to as high as 8.6 mm in the month of July, with an annual mean of 5.4 mm per day (Table 2.5). At no point of the year, precipitation is more than evaporation even during the monsoon which is quite characteristic of the arid climate. The climatic water balance of Lakhpat, that is representative of the sub-region is furnished below.

The mean annual temperature ranges between 25 and 27 ^{0}C, rising to a maximum of 32 ^{0}C during summer. During some days of the summer months, temperature raises to more than 40 ^{0}C. It goes down to 15 ^{0}C in January and in some days of the winter season, to below 5 ^{0}C. The mean annual water deficit is around 1600 mm. The moisture index is more than 80%, indicating hyper-aridic conditions and LGP is less than 60 days.

The effective rainfall is more than 80%, indicating scope for only *in situ* moisture conservation as not much runoff is expected during the monsoon season. The soil moisture control section (SMCS) remains dry for most part of the year, except for some brief period during July-August. Thus, the moisture availability period (LGP) is less than 60 days and that too only during July and August, which is categorized as intermediate type. In addition to the soil remaining dry for more than 300 days, the salinity also restricts the moisture availability to the plants. All these indicate that the soil moisture regime for crop growth in this sub-region is aridic. The mean annual soil temperature is more than 22 ^{0}C.

AESR 2.3

The rainfall varies between 309 and 575 mm in different locations of the sub-region with an average of 483 mm annually (Table 2.6). The monsoon starts from the third week of June and practically ends by the end of September, accounting for 90% of the rainfall received. During rest of the months, mean monthly rainfall does not exceed 10 mm. The annual mean effective rainfall is 89%. But, from October to May, effective rainfall is between 98 and 100%. Only during July and August, the effective rainfall is below 90% and in the months of June and September, it is around 95%. The rainfall probability of more than 300 mm is less than 50%.

The mean annual PE is 1695 mm with a range of 1380 to 2041 mm at different representative locations of the sub-region. Annual precipitation is only 28% of the evaporation. During all the months of the year, evaporation is more than precipitation (Fig. 2.3) and only during the

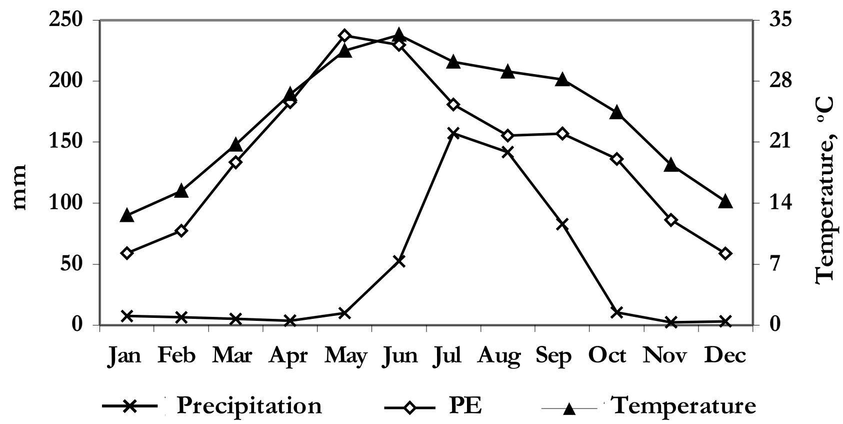

Figure 2.3: Climatic water balance for AESR 2.3

month of August, the precipitation approaches the value of the evaporation. The mean daily evaporation is 4.6 mm with a mean daily maximum evaporation of 7.9 mm in May and a mean minimum daily evaporation of 1.9 mm during December (Table 2.8). Except in some locations of Haryana and the Sami of Gujarat where some soil storage is recorded, in all other parts of this sub- region no soil storage is observed. The water deficit occurs in the range of 885-1494 mm annually. The moisture index ranges between – 64 to – 85%, indicating the typic-arid conditions. The length of growing period is between 60 and 90 days. Agro-climatically, the sub-region is experiencing hot typic arid conditions with hot and dry summer and cold winter. The difference between mean summer soil temperature (MSST) and mean winter soil temperature (MWST) is more than 5 ^{0}C with the mean annual soil temperature of more than 22 ^{0}C, indicating hyper-thermic soil temperature regime. Moisture availability is thin, in spite of the fact that the effective rainfall in this sub-region is around 90%. This is due to very low rainfall and sandy soil conditions. Moisture availability, even for a single season crop, is the critical constraint for crop production. Hence, only with supplement irrigation, crops like groundnut, cotton, etc can be grown.

AESR 2.4

This sub-region is characterized by hot typical arid climate with dry summer and cold winters. The annual rainfall at different locations in this sub region ranges from 350 to 550 mm with an average of around

Table 2.6: Climatic water balance of AESR 2.3

(mm)

Particulars	Bhiwani	Hissar	Pali	Sirohi	Jalore	Nagaur	Jhunjhunu	Churu	Sami
Precipitation (P)	414	428	564	575	363	309	387	368	516
Potential evaporation (PE)	1426	1609	1857	1380	1857	2041	1503	1771	1750
P–PE	–1012	–1181	–1293	–805	–1494	–1731	–1115	–1403	–1234
Storage	2	6	88	297	0	0	0	0	278
Actual evapotranspiration (ET_a)	414	428	564	495	363	310	387	368	569
Water deficit (WD)	1012	1182	1293	885	1494	1731	1115	1403	1180
Water surplus (WS)	0	0	0	79	0	0	0	0	0
Accumulative potential water loss (APWL)	–6644	–7018	–7500	–4327	–8222	–10714	–6104	–9487	–5486
Available water capacity (AWC)	200	200	100	100	100	100	100	100	100
Humidity index (I_h), %	0	0	0	0	0	0	0	0	0
Aridity index (I_a), %	70.95	73.39	69.61	64.11	80.45	84.82	74.25	79.25	67.45
Moisture index (I_m), %	–70.95	–73.39	–69.61	–64.11	–80.45	–84.82	–74.25	–79.25	–67.45

400 mm (Table 2.7). The very high CV of rainfall is the characteristic of this sub-region. The probability of getting more than 30 mm of rainfall hardly exceeds 50%. The monsoon starts from 3rd week of June and extends up to the end of September and during this period 95% of the total rainfall is received.

The mean effective rainfall (ER) is around 77% of total precipitation. But among different months, the ER was 100% during the non rainy months of November to May. When the monsoon starts during June, the ER goes down and it is lowest during July with a figure of 65%. The mean ER during the monsoon months is 76%.

The mean pan evaporation is close to 2000 mm, which works to almost five times of the rainfall. In other words the precipitation is hardly 20-25% of the evaporation. The water balance diagram (Fig. 2.4) clearly brings out the fact that at no time of the year the precipitation is more than that of evaporation. Even during the monsoon season at no time the precipitation even equals the evaporation and always it is lower than the PE. The P-PE values are always 1500 and 1600 mm for the different locations of the sub-region with a mean of 1566 mm. The mean monthly evaporation is minimum during December and is around 100 mm up to February. Subsequently it increases and records a value of 200 mm and above up to July and then recedes gradually with a small jump during October. The mean daily evaporation varies between 3 mm during December-January and 9 mm recorded during May with an average of 5 mm/day during the year (Table 2.9).

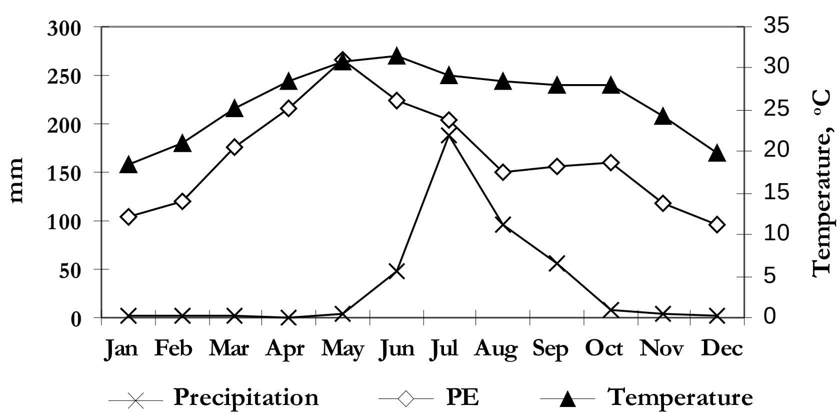

Figure 2.4: Climatic water balance for AESR 2.4

Table 2.7: Climatic water balance of AESR 2.4

(mm)

Particulars	Bhachhau	Mundra	Rapar	Dwaraka	Morbi	Wankaner	Abadasa	Mean
Precipitation (P)	373	379	361	353	533	549	314	409
Potential evaporation (PE)	1987	1987	1897	1773	2144	2144	1897	1976
P–PE	-1614	-1608	-1531	-1419	-1610	-1595	-1583	-1566
Storage	76	84	156	116	339	315	121	172
Actual evapotranspiration (ET_a)	475	491	468	354	611	627	419	492
Water deficit (WD)	1512	1496	1429	1419	1533	1517	1478	1483
Water surplus (WS)	0	0	0	0	0	0	0	0
Accumulative potential water loss (APWL)	-9220	-9214	-7648	-8041	-7965	-8048	-8156	-5695
Available water capacity (AWC)	100	100	100	100	150	150	100	114
Humidity index (I_h), %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aridity index (I_a), %	76.08	75.30	75.34	80.06	71.52	70.76	77.92	75.28
Moisture index (I_m), %	-76.08	-75.30	-75.34	-80.06	-71.52	-70.76	-77.92	-75.28

Table 2.8: Mean monthly climatic water balance of AESR 2.3

(mm)

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Precipitation (P)	7.5	6.5	5.1	3.7	9.8	52.4	157.3	141.7	82.9	10.3	2.4	3.3	483
Potential evaporation (PE)	59.1	77.5	133.5	182.8	237.6	229.6	180.8	155.3	156.9	136.2	86.3	58.8	1694.5
Temperature (°C)	12.6	15.4	20.7	26.5	31.5	33.3	30.2	29.1	28.2	24.4	18.4	14.2	23.7*
Effective rainfall (%)	100	99	98	100	98	95	86	84	93	100	100	100	89
Potential evaporation (mm/day)	2.0	2.6	4.5	6.1	7.9	7.7	6.0	5.2	5.2	4.5	2.9	1.9	4.6

*Annual mean value

Table 2.9: Mean monthly climatic water balance of AESR 2.4

(mm)

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Precipitation (P)	1.2	2.1	2.0	0.6	3.5	47.4	187.7	95.2	56.1	8.4	4.4	1.3	409.9
Potential evaporation (PE)	104.6	120.1	175.6	216.5	266.2	223.0	203.3	149.5	155.1	160.1	118.3	96.0	1988.4
Temperature (°C)	18.5	20.9	25.2	28.4	30.7	31.5	29.2	28.4	27.9	27.9	24.2	19.9	26.1*
Effective rainfall (%)	100	100	100	100	99	90	65	80	90	99	100	100	77
Potential evaporation (mm/day)	3.5	4.0	5.9	7.2	8.9	7.4	6.8	5.0	5.2	5.3	3.9	3.2	5.4

*Annual mean value

The water deficit, which is the difference between the Actual and Potential Evapotranspiration, is 1480 mm. It is maximum (between 175 and 250 mm) during April to June and with the onset of monsoon it drops down to 20 mm. It then increases slowly up to October and decreases further till April. The moisture index values, which are around –70 to –80 indicates the typical arid conditions of the sub region. The mean annual temperature ranges between 26 ^{0}C and 27 ^{0}C rising to a maximum of more than 40 ^{0}C during May. The winters are also very cold and the temperatures are lowest during January.

The soil moisture control section remains dry for more than 270 cumulative days in a year and this sub-region is classified under Aridic/ Torric soil moisture regime and since the mean soil temperature is more than 22 ^{0}C and the MSST and MWST differs by more than 5 ^{0}C, the soil temperature regime is hyperthermic.

Soils

AESR 2.1

The soils of this sub-region are of aeolian and/or alluvium-derived. Irrespective of their association with either dunes or creeps, they are deep, excessively drained, calcareous or non-calcareous and sandy in nature. They occur commonly on the gently or moderately gently sloping dunes or gently sloping interdunal plains as either dominant or sub-dominant soils. Taxonomically, two orders occur in this sub-region. The major one is Entisols and the other occurring to a lesser extent and confined to the interdunal plains is Aridisols. Among the different soil types, the *Typic Torripsamments* is the most widely occurring one and the types of Aridisols occurring less extensively are, *Typic Calciorthids, Typic Paleorthids* and *Typic Salorthids*.

Thar series is the most important and wide-spread soil occurring in AESR 2.1 (Table 2.10). This is a member of the mixed, hyperthermic family *Typic Torripsamments*. Texturally, they are sandy in nature with the sand percentage varying between 83.2 and 91.7%, with a tendency for slight increase with depth. On the other hand, the silt per cent tends to decrease with the depth though they contribute to only 6.3 to 10%. The clay content, which varies between 5 and 7%, does not show any trend with regard to its distribution in the profile. These soils are neutral

Table 2.10: Important profile characteristics of *Thar* series

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	O C (%)	$CaCO_3$ (%)	$pH_{2.5}$	AWC (%)	CEC [cmol (p^+) g^{-1}]
0–38	84.5	9.8	5.7	0.10	6.0	8.0	3.0	2.3
38–92	83.2	10.0	6.8	0.12	6.6	8.2	3.6	2.2
92–108	86.1	7.4	6.5	0.10	8.0	8.2	2.5	2.4
108–138	86.7	6.3	7.0	0.01	8.2	8.2	2.1	2.6
138–160	91.7	6.3	5.0	0.01	7.3	8.3	1.3	2.5

to alkaline, with low organic carbon (OC), phosphorus and zinc contents. They are low-to-medium in productivity potential. They are well drained with rapid permeability. Land capability class of this series is VIc and the irrigability sub-class is low-to-medium. They are mostly used for grazing, though under certain conditions pearl millet and horse gram are grown.

Another important recognized series is the *Masitwali* series (Table 2.11), which is a member of the coarse loamy, mixed, hyperthermic family of *Typic Torrifluents.* These occur extensively in the flood plains of north-west portion of the sub-region. They are well drained with rapid permeability. Their land capability class is IVe and irrigability sub-class is 2s with medium productivity potential. The natural vegetations are *Calotropis* spp., *Prosopis* sp. and *Haloxylon* spp. Cotton, sugarcane, wheat, gram, mustard and cluster beans are the commonly cultivated crops on this soil series. The *Salorthids* are the typical salt, affected saline soils occurring in this sub-region.

Table 2.11: Profile characteristics of *Masitawali* series

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	O C (%)	$CaCO_3$ (%)	$pH_{2.5}$	$EC_{2.5}$ (dS/m)	AWC (%)	CEC [cmol $(p^+)kg^{-1}$]
0-15	72.5	16.0	11.5	0.16	1.6	8.0	0.50	5.1	3.7
15-29	65.9	15.6	18.5	0.12	1.1	8.0	0.45	5.9	4.0
29-45	62.0	21.9	16.1	0.12	2.1	8.0	0.36	6.4	4.5
45-84	60.1	21.0	18.9	0.12	2.2	8.2	0.41	7.8	4.3
84-124	70.6	16.2	13.2	0.09	7.1	8.2	0.35	6.2	3.7
124-150	70.6	19.2	10.2	0.07	7.1	8.1	0.40	5.4	3.4

AESR 2.2

These soils occur on gently sloping to nearly level soil capes represented by the great groups, *Salorthids* and *Natrargids* in association with *Camborthids* in some pockets. The *Natrargids*, which are deep, clayey strongly sodic in nature occur in an extensive area. Gypsum layers are encountered at various depths in these soils and they are saline or sodic or saline-sodic in nature. The *Lakhpat* series (Table 2.12) is an important identified series and this comprises members of fine, mixed hyperthermic family of *Typic Natragids* and occur on very gently sloping to level lands. These are imperfectly drained, moderately to strongly alkaline clayey in texture and clay content, which varies from 40 to 50% and decreases with depth. The ESP, which varies from 13 to 35% and increases with depth. The land capability is IVs and the irrigability sub-class is 3d due to poor drainage, with low productivity potential. The permeability of these soils is poor.

Table 2.12 Profile characteristics of *Lakhpat* series

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	OC (%)	$CaCO_3$ (%)	$pH_{2.5}$	$EC_{2.5}$ (dS/m)	ESP
0-10	41.1	17.3	41.6	0.29	1.3	8.7	0.20	13
10-45	33.4	14.8	51.8	0.18	2.3	8.6	1.70	22
45-83	37.0	14.2	48.8	0.20	3.7	8.4	4.50	26
83-117	36.5	16.7	46.8	0.18	1.8	8.2	6.50	29
117-150	32.2	25.8	42.0	0.10	2.1	8.3	5.50	35

The *Banni* area, which is a very important part of this sub-zone, is an alluvial flat occupying an area of 2 lakh hectares. It is a low-lying tract. Though it is a part of the highly salt-affected Rann of Kutch, deposition of sand and silt by rivers has improved the vegetation, which is mainly mesophytic species with sporadic halophytes. Saucer-shaped topography; proned to tidal ingress through Kori creek characterizes this region. The soils are of recent origin and mostly belong to *Orthids, Argids* and *Psamments.*

A typical soil series (Table 2.13) occurring extensively in Banni area is classified into fine loamy mixed, *hyperthermic* family of Typic *Salorthids*. The texture varies from clay loam in the surface to silty clay loam in the sub-surface. They are highly saline sodic with an EC value of more than 30 dS/m and ESP exceeding even 70%. At many places, groundwater level of less than 2 m is encountered even during summer.

Table 2.13: Profile characteristics of soils of *Banni* area

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	OC (%)	$CaCO_3$ (%)	$pH_{2.5}$	$EC_{2.5}$ (dS/m)	ESP
0-13	23.0	42.0	35.0	0.30	5.9	8.4	33.5	74
13-30	5.0	52.0	43.0	0.13	7.4	8.4	35.2	62
30-102	6.4	65.3	28.3	0.08	15.2	8.3	22.6	70
102-134	4.4	67.3	28.3	0.08	16.2	8.2	23.5	72
134-170	4.4	67.3	28.3	0.08	14.2	8.0	21.8	72

AESR 2.3

The dominant soil groups occurring in this sub-region are *Calciorthids* and *Camborthids*. At some places when the soil occurs at shallow depth *Natrargids* and *Salorthids* occur. The soils occurring in gently undulating sandy loams fall under *Torripsamments*.

A typical soil series occurring in Pali district is *Pali* series (Table 2.14), which is a member of fine loamy mixed hyper-thermic family of *Lithic Calciorthids*. They occur on nearly level to gently sloping plains. The solum thickness is 25 to 50 cm. The soils are shallow and have low moisture-holding capacity. Run-off losses are estimated to be 15 to 20% of rainfall, which further aggravate the moisture deficit. Texturally, the sand percentage decreases with depth and ranges between 38 and 46.3%, while that of clay between 17.9 and 28%, with a tendency to increase with depth. The silt fraction, which is around 33.9 to 36.4%, is more or less constant at different depths. Soil reaction is more alkaline at the surface and tends to get reduced with depth. They are well drained to having moderate permeability. They occur extensively in Pali and Jalore districts. These soils are poor in fertility and prone to leaching losses of nutrients. The productivity potential is medium with land

Table 2.14: Profile characteristics of *Pali* series

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	OC (%)	$pH_{2.5}$	$EC_{2.5}$ (dS/m)	CEC [cmol(p^+)kg^{-1}]
0-10	46.3	35.8	17.9	0.37	8.1	1.49	6.7
10-22	43.9	36.4	19.7	0.37	7.9	1.39	7.0
22-34	38.0	35.8	26.2	0.46	7.8	1.36	7.2
34-44	38.1	33.9	28.0	0.42	7.8	1.39	8.1

capability sub-class as IVc and irrigability sub-class as 2s. High temperature, low rainfall and severe wind erosion are some of the major soil productivity constraints.

AESR 2.4

Aridisol is the major soil order existing in this sub-region followed by Entisols and Inceptisols. Based on the normal classification, four broad groups of soils are identified in this sub-region. They are sandy soils, black soils, hydromorphic soils and highly salt affected soils. The sandy soil group consists of Orthids, Psamments and Ochrepts. They are basically sandy to sandy loam in texture and are deep well drained yellowish brown to dark yellowish brown in colour with poor development of structure. The soil reaction is neutral to alkaline. They are calcareous in nature and salt affected in many places. The Black soils are mostly Aridisols belonging to Orthids/Argids or Ochrepts or Usterts. In this group the soils are sandy clay loam to silty clay loam in texture and dark in colour. In many places they are salt affected (Saline or sodic or saline sodic). The hydromorphic soils fall under Ochrept-Asquept association. They are sandy loam in the surface and sandy clay loam to clay loam in the sub surface horizon. They are highly and widely salt affected and are water logged with a high saline water table.

The highly salt affected soils occur on the border of Rann of Kutch in this sub region. They are extremely salt affected and mostly barren and uncultivated. They are fine textured and contain large quantities of chlorides and sulphates of Calcium, Magnesium and Sodium. Gypseferous layers are encountered at various depths of the profile. They show high degree of glazing with black matrix on the epipedon. Reddish brown horizons of iron accumulation occur in the substratum. The salinity value increases with the depth. Except the hydromorphic soil all other soil groups are low in nitrogen, medium in phosphorus and sufficient in potash. The profile characteristics of the representative soil series are presented in Table 2.15. The *Adesar* series is a member of the fine, mixed, hyperthermic family of *Typic Paleargids*. The soils have yellowish moderately alkaline red gravelly sandy clay loam A horizon, with gravelly clay loam B horizon and reddish brown C horizon. They are moderately well drained with moderate permeability. They are normally cultivated with cotton, sorghum and pearl millet. These soils are droughty and prone to become sodic. Provision of drainage is a must for these types of soils for practicing irrigated agriculture.

Table 2.15: Profile Characteristics of *Adesar* soil series

Depth (cm)	Sand %	Silt %	Clay %	$pH_{2.5}$	$EC_{2.5}$ (dS/m)	O C (%)	CEC [cmol $(p^+)kg^{-1}$]
0-8	74.6	3.5	21.9	8.3	0.23	0.8	34.8
8-38	56.5	7.0	36.5	8.6	0.30	0.4	33.9
38-75	48.4	11.2	40.4	8.0	0.61	0.6	33.9
75-127	39.3	21.4	39.3	8.8	0.80	0.6	29.6

Another identified profile, which is a representation of saline soil, is a one from Satapur of Anjar taluka (Table 2.16). It belongs to fine, mixed hyperthermic family of *Typic Natrargids*-saline phase. The pH of the saturation extract varies between 7.6 and 8.5 in different layers without any trend with the depth. On the other hand the salinity increases with the depth up to 108 cm and then tends to decrease. There is a regular increase in the clay content with the depth resulting in argillic horizonation. They are highly calcareous in nature and the calcium carbonate content increases with depth up to 108 cm and then tends to get reduced gradually. The SAR of the soil solution varies between 5.9 in the 0-19 cm depth and abruptly increases to 30 cm and above in all other layers.

Table 2.16: Profile Characteristics of a Typical *Natrargids*-Saline Phase

Depth (cm)	Sand %	Silt %	Clay %	$pH_{2.5}$	$EC_{2.5}$ (dS/m)	SAR	CEC [cmol $(p^+)kg^{-1}$]
0-19	54.2	24.0	21.8	8.3	1.5	5.9	19.8
19-38	34.2	16.0	49.8	8.5	6.8	30.1	19.8
38-61	24.2	22.0	57.8	7.9	17.5	36.5	28.4
61-80	18.2	18.0	63.8	7.6	18.5	36.5	30.5
80-108	20.2	18.0	61.8	7.8	20.0	39.5	53.8
108-130	19.0	16.0	65.0	8.1	16.8	27.2	55.5
130-160	15.0	10.0	75.0	7.9	14.5	31.7	47.6

Agriculture and Land Use Pattern

Less than half of the geographical area in AER 2 is coming under the cultivation of agricultural crops (Table 2.17). Culturable waste lands account for 17.3% of the geographical area followed by 9.8% under barren lands. Current fallows and other fallows constitute 13.8% of the area. Permanent pastures and forest area account for only 3.5% each in AER 2. Gross cropped area in this region is 19.4 M ha with a cropping intensity of 125%. AESR wise land use pattern is presented in table 2.17.

In AESR 2.1, net cropped area occupies 37.2% of the geographical area. Culturable waste land is maximum in this sub-region, which accounts for 28.2% of the geographical area. Current and other fallows constitute nearly one-fifth of the geographical area in AESR 2.1. Proportionate area under forests is least in this AESR and permanent pasture lands also occupy only 3.5% of the area. Cropping intensity is only 116%. In AESR 2.3, 66.5% of the geographical area is put under the cultivation of agricultural crops. Cropping intensity is maximum at 137% in this sub-region. Current and other fallows occupy 12% of the geographical area in AESR 2.3.

The data presented in the Table 2.17 for AESR 2.4 also includes AESR 2.2. Percentage of geographical area brought under agricultural crops is least in these sub-regions. Barren lands and culturable waste lands occupy 28% of the geographical area. Pressure on land for producing the food, fodder and fuel is relatively high in this sub-region as compared to other sub-regions of AER 2.

Area, production and productivity

The area, production and productivity status for major crops in AER 2 and various sub-regions of AER 2 are presented in Table 2.18. Cereals occupy 41.4% of the gross cropped area followed by oilseeds (15.7%) and pulses (16.6%). Cotton is also important crop with 7% of the gross cropped area getting allocated for it. Pearl millet and wheat are the predominantly grown cereals crops in this AER 2. More than 80 per cent of the area under cereals are under these crops. Rapeseed and mustard and ground nut are the important oilseed crops grown in AER 2. Chick pea is the major pulse crop grown in this region.

In AESR 2.1, Cereals are the major crops grown in 42% of the gross cropped area. Pearl millet and wheat occupies 96% of the area under cereals. Next to cereals, pulses are important in the cropping pattern. Nearly one-fourth of the gross cropped area is put under pulse crops. Chick pea is the major pulse crop. Rapeseed and mustard is important oilseed crop grown in 7.2% of the gross cropped area sown in this sub-region. In AESR 2.3, cereal crops accounted for 48.8% of the gross

Table 2.17: Land use statistics in AER 2

Land Use	AESR 2.1		AESR 2.3		AESR 2.4		AER 2	
	Area in '000 ha	Percentage of geographical area	Area in '000 ha	Percentage of geographical area	Area in '000 ha	Percentage of geographical area	Area in '000 ha	Percentage of geographical area
Geographical area [@]	13704	100.0	11596	100.0	8147	100.0	33447	100.0
Forest area	204	1.5	566	4.9	416	5.1	1186	3.5
Barren lands	688	5.0	488	4.2	2092	25.7	3267	9.8
Non-agriculture uses	622	4.5	557	4.8	260	3.2	1439	4.3
Culturable waste lands	3870	28.2	165	1.4	1738	21.3	5772	17.3
Permanent pastures	488	3.6	441	3.8	280	3.4	1210	3.6
Other fallows	1401	10.2	573	4.9	11	0.1	1985	5.9
Current fallows	1335	9.7	1063	9.2	237	2.9	2635	7.9
Net cropped area	5094	37.2	7708	66.5	2696	33.1	15497	46.3
Gross cropped area	5898	43.0	10547	90.9	2918	35.8	19364	57.9
Cropping intensity %	116	-	137	-	108	-	125	-

[@] As a total of the eight land-uses given in the table. Hence, this do not equal to the total geographical area of respective sub-regions

Note : Reference Year 1999-2000

Table 2.18: Area and Productivity of major crops in AER 2

Crops	AESR 2.1		AESR 2.3		AESR 2.4		AER 2	
	Area Per cent of GCA	Yield Kg/ha	Area in Per cent of GCA	Yield Kg/ha	Area in Per cent of GCA	Yield Kg/ha	Area in Per cent of GCA	Yield Kg/ha
Rice	0.7	2364	5.0	3216	0.0	1751	3.0	3150
Wheat	10.8	2863	18.4	3716	3.0	2682	13.8	3478
Sorghum	0.4	428	1.5	247	0.5	533	1.0	292
Pearl millet	29.7	314	22.5	429	9.7	901	22.8	414
Maize	0.0	1036	0.7	1221	0.0	0.0	0.4	1220
Barley	0.3	2099	0.7	2499	0.0	0.0	0.5	2418
Total cereals	42.0	1020	48.8	1989	13.3	1292	41.4	1656
Ground nut	0.4	1517	0.5	1151	31.5	1102	5.1	1115
Sesamum	1.4	256	1.4	129	5.2	451	2.0	284
Rapeseed & Mustard	7.2	1108	8.9	1081	0.4	1385	7.1	1092
Castor	0.2	1163	0.6	388	0.0	0.0	0.4	497
Total oilseeds	9.2	997	12.7	985	39.9	1097	15.7	1030
Chick pea	10.1	748	8.0	850	0.0	0.0	7.4	808
Pigeon pea	0.0	750	0.0	997	0.0	0.0	0.0	977
Other pulses	13.7	277	7.6	265	0.0	0.0	8.3	271
Total pulses	23.8	477	15.6	566	5.4	452	16.6	521
Cotton	8.4	297	8.1	1570	0.0	0.0	7.0	1103
Total major crops	83		85		59		81	

Note : Reference Year 1999-2000

cropped area. Among cereal crops, pearl millet and wheat are the major dominating crops covering 41% of the area. Rice occupies 5% of the gross cropped area in this sub-region. Rapeseed and mustard is the dominant oilseed crop grown in 70% of the area under oilseeds. Pulse crops are grown in 15.6% of the area and in over half of this area, chick pea is cultivated. Cotton is also important crop covering 8.1% of the GCA in this sub-region. The cropping pattern presented in Table 2.18 area for AESR 2.4 also includes AESR 2.2. In these sub-regions, oilseeds are the major crops grown in 40% of the gross cropped area followed by cereals in 13.3% of the area. Among all the crops, ground nut is the most important crop cultivated in 31.5% of the gross cropped area.

Thus, wide diversity is observed in the cropping pattern across AESRs within the AER 2. While it is cereals-dominated cropping pattern in AESR 2.1 and 2.3, it is oilseeds-dominated cropping pattern in case of AESR 2.2 and 2.4. While pearl millet, wheat, chick pea, cotton and rapeseed and mustard are the major crops grown in AESRs 2.1 and 2.3, Groundnut, pearl millet and sesamum are the major crops cultivated in AESRs 2.2 and 2.4. Crop productivity also varies across the sub-regions. Wheat and chick pea yields are high in AESR 2.3. Average groundnut yield is 1.5 t/ha in AESR 2.1, which is highest among the sub-regions of AER 2. In AESR 2.4, average rapeseed and mustard yield is 1.4 t/ha, which is highest among the sub-regions of AER 2.

Livestock Status

The total livestock population in AESR 2.1 is about 127.3 lakh. The sheep and goats together constituted 61% of the livestock population of which sheep population is more than goats. The cattle and buffalo together constitute one third of the population. The density of the livestock population is 1.77 per hectare of the gross cultivated area (Table 2.19).

Animal husbandry occupies a very important position in the socio-economic status of the farmers in AESR 2.2. Cattle breeding has remained the main occupation in the Banni area in the past. Of late it is more of cattle grazing rather than cattle breeding in this area. The cattle and goat population together make up to 50% of the livestock population. But sheep with a population of 72000 accounts for 32% of the livestock population. With a cultivated area of 40000 ha, the density of the livestock population in this sub-region is highest at 5.6 per hectare.

Table 2.19: Livestock composition of AER 2

Sub-region	Population in '000 numbers						Density
	Cattle	Buffalo	Sheep	Goats	Others	Total	
AESR 2.1	2215	1797	4391	3484	845	12732	1.77
% to total	17	14	34	27	7	100	
AESR 2.2	58	19	72	60	18	227	5.60
% to total	25	9	32	27	8	100	
AESR 2.3	9258	8717	10864	7893	3164	39895	1.83
% to total	23	22	27	20	8	100	
Rajasthan	7220	5594	9997	6901	2340	32052	2.61
% to total	23	17	31	22	7	100	
Punjab	705	1014	200	177	105	2201	1.39
% to total	32	46	9	8	5	100	
Gujarat	666	802	141	447	211	2267	2.02
% to total	29	35	6	20	9	100	
Haryana	667	1307	526	368	508	3376	1.28
% to total	20	39	16	11	15	100	
AESR 2.4	1800	811	1157	1092	450	5312	2.40
% to total	34	15	22	21	8		

The total cattle population in AESR 2.3 is around 400 lakh, 80% of which is present in Rajasthan part of sub-region. The population is 22 lakh each in Punjab and Gujarat, while in Haryana it is 34 lakh. Though at the sub-region level cattle, buffalo, sheep and goat contribute almost equally to the total cattle population, in Rajasthan sheep population alone contributes to one third of the total population. On the other hand in Punjab, Haryana and Gujarat portions of the sub-region, buffalo is the major livestock contributing to about 40% of the population. The livestock density per hectare of gross cultivated area was found to vary between 1.28 in Haryana and 2.61 in the Rajasthan part of sub-region.

In AESR 2.4, the total livestock population is 53 lakh in 20.6 lakh hectare of cultivated area working out to a density of 2.4 per hectare. The cattle population of 18 lakh is the maximum followed by sheep with a population of 11.6 lakh and goats (10.9 lakh) in that order. The buffalo population contributes to only 15% of the total population.

Land Holdings

There are 3.33 million farm holdings operating 18.4 M ha of land in AER 2 (Table 2.20). Average holding size of the farm is 5.5 ha. One-third of the farm holdings in this AER is small and marginal farms, each operating less than 2 ha. Only 6% of the land area is cultivated by 33% of the farm holdings. Over 43% of the farms are large holdings operating over 81% of the land area. There are wide variations across sub-regions. AESRs 2.2 and 2.4 are combined in the Table 2.20.

Table 2.20: Distribution of farm holding size in AER 2

Farm sizes	AESR 2.1	AESR 2.3	AESR 2.4	AER 2
	Number			
Marginal holdings	39765	419830	62100	521695
Small holdings	67915	345566	165542	579023
Medium holdings	151387	428608	215389	795384
Large holdings	594218	584222	257988	1436428
Total	853285	1778226	701019	3332530
	Area (ha)			
Marginal holdings	22581	218228	41755	282564
Small holdings	101748	493602	249348	844698
Medium holdings	451479	1222030	611815	2285325
Large holdings	7516843	5567663	2039791	15124297
Total	8092653	7501524	2942709	18536885
	Number (% to total)			
Marginal holdings	4.7	23.6	8.9	15.7
Small holdings	8.0	19.4	23.6	17.4
Medium holdings	17.7	24.1	30.7	23.9
Large holdings	69.6	32.9	36.8	43.1
Total	100.0	100.0	100.0	100.0
	Area (% to total)			
Marginal holdings	0.3	2.9	1.4	1.5
Small holdings	1.3	6.6	8.5	4.6
Medium holdings	5.6	16.3	20.8	12.3
Large holdings	92.9	74.2	69.3	81.6
Total	100.0	100.0	100.0	100.0

In AESR 2.1, only 12.7% of the farms are small and marginal farms as against 43% in AESR 2.3. Nearly 70% of the farm holdings are large farms operating more than 4 ha in AESR 2.1. Average farm holding size is 9.5 ha which is highest among the sub-regions of AER 2. This sub-region (AESR 2.1) covers mostly west arid zone and north arid zone districts of Rajasthan and southern tips of Firozepur district of Punjab. Thus, a skewed distribution of farm holdings across various sizes as well as sub-regions is observed in AER 2.

Water Resources and Irrigation

AESR 2.1

Physiographically, the sub-region can be divided into two distinct regions. The north part of the sub-region is plains, while the south-west part is dominated by desert and sand dunes gently sloping from the Aravalli foothills to the Indo-Pak border. Out of the 13 river basins existing in the state of Rajasthan, only one river basin, viz. Luni is present in this sub-region. Eighteen per cent of this basin is located in the Barmer district and another 5% in the Jodhpur district of the sub-region. The rest of the districts in this sub-region contribute to the bulk (75%) of the area under "Out side basin".

Water availability

The basin-wise and source-wise break-up of the total water available in the sub-region is presented in Table 2.21.

Irrigation status and sources

The sub-region is mainly rainfed, as only 20% of the cultivated area is under irrigation. The irrigated agriculture is mainly practised in the "plains" of Ganganagar district (Table 2.22).

Out of 8 lakh hectares of net sown area, 4.8 lakh ha receive irrigation in Ganganagar district in North arid zone. On the other hand, in West arid zone, with a net sown area of 55 lakh hectares, only 8 lakh hectares are under irrigation. In the West arid zone, net irrigated area has expanded at the rate of 7% during the last decade. This variation in the irrigation status among the districts has reflected on the crop concentration, their productivity and the total production in this sub-region.

Table 2.21: Total water availability in AESR 2.1

(BCM)

Basins	Groundwater	Surface water	Inter-state basins	Total
Luni	0.40	0.20	0.15	0.75
Out side basin*	2.50	-	11.82	14.32
AESR 2.1	2.90	0.20	11.97	15.07

*Contributed by Ganga Canal (1023 MCM), Bhakra (1383 MCM), Ravi-Beas (7921 MCM), Chambal Kota (1477 MCM), Narmada (462 MCM), Gurgaon Canal (83 MCM) and Bharatpur feeder (18 MCM).

Only two systems viz. canal and groundwater lift systems of irrigation are prevalent in this sub-region. In the Ganganagar district source of irrigation is predominantly through the canal system (99.6%). On the other hand, in the West arid part of the sub-region, groundwater is the major source amounting to two third of the irrigated area. At the sub-region level, the contribution from canal exceeds the ground water. The groundwater utilization is to the tune of 32% in the North arid part and it is more than double (66%) in the West arid part. During the decade, groundwater balance was found to decline at the rate of 8.6% in the West arid zone while at the sub-region level the indication is that the groundwater balance was declining at the rate of 2.2%.

This sub-region has to depend heavily upon the interstate basin water resource as 80% of the potentially available water is from interstate basin source. The surface water available locally is only 1.3%. Groundwater

Table 2.22: Irrigation status in AESR 2.1

Distribution	Net irrigated area		Per cent of irrigated area		Groundwater status	
	Lakh ha	per cent to NSA	Canal	Ground-water	Utilized %	Balance (MCM per annum)
North arid	4.8	60	99.6	0.4	32	90
Decadal change, %	-4.1		-4.2	9.9		4.3
West arid	8.0	14	32.9	67.0	66	724
Decadal change, %	7.4		22.1	4.2		- 8.6
Sub-region	12.8	20	57.9	42.0	49	814
Decadal change, %	1.6		9.0	7.0		-2.2

contributes to 19% of the total water availability. But, between the two basins, there exists a wide variation. In Luni basin, contributions from groundwater, surface water and interstate basins are 53%, 27%and 20%, respectively and the corresponding figures for out side basin are: 17%, zero and 83%(Table 2.21).

The extent of groundwater exploitation is reflected in the Table 2.23. In Ganganagar district there has been an increase in groundwater level over a seven-year period ending 1990 to an extent of 2.2 MCM. In other districts of this sub-region, there has been a decline in groundwater level ranging from as low as 0.2 MCM in Bikaner to 192.5 MCM in Jodhpur (Table 2.23).

Table 2.23: Change in groundwater status between 1983 and 1990

(MCM)

District	Change
Barmer	-11.6
Bikaner	-0.2
Ganganagar	+2.2
Jodhpur	-192.5

Basin-wise groundwater situation

The groundwater situation in this sub-region is influenced by two basins namely Luni basin and "out side basin" situations. The differential trend between two basins indicates that in Luni basin groundwater is over-exploited (Table 2.24) while in out side basin, its utilization is only 40%.

One of the main reasons for this is high amount of surface water available from the interstate basins in comparison to the groundwater availability

Table 2.24: Basin-wise groundwater development in AESR 2.1

(MCM)

Basins	Draft	Recharge	Development (%)
Luni	354	316	112
Out side basin	959	2482	39
AESR 2.1	1313	2898	45

in this basin. North arid zone, which is a canal command area of this sub-region, is a white zone. Here conjunctive use of water should be encouraged at a price that can be competitive with that of the canal water so that water-logging problem could be prevented.

Water availability projection

As per the present and projected basin-wise water needs for irrigation and non-irrigation sectors estimated by the Government of Rajasthan, the demand for water by different sectors, which is presently at 896 MCM is expected to go up to 1234 MCM (Table 2.25). As against this, there would be around 3% decline in the water availability for irrigation in this sub-region.

Table 2.25: Basin-wise demand for water

(MCM)

Basins	Total estimated availability	Demand for non irrigation uses		Demand for irrigation		Decrease (%)
		1995	2015	1995	2015	
Luni	706	92	110	614	596	3
Outside	14300	804	1124	13496	13176	2.4
AESR 2.1	15006	896	1234	14110	13772	2.4

Quality of ground water

The groundwater in all districts of this sub-region is showing salinity problems to varying extents (Table 2.26).

The water from Barmer is relatively more saline than that of Ganganagar. Extent of groundwater with salinity level of less than 3 dS/m in 32% and 60%, respectively for Barmer and Ganganagar districts. The other districts fall in between. The sodium adsorption ratio (SAR) values, which indicate the predominance of sodium, also follow the same trend. Although more than 60% of the water in all the districts is having residual sodium carbonate (RSC) values of less than 2.5, more than 30% of the water from Barmer and Jaiselmer districts is having high RSC values to categorize them as sodic. The water from Ganganagar district is having minimum water sodicity problem.

Table 2.26: Groundwater quality in selected districts of AESR 2.2

(percentage of samples)

Classes	Barmer	Bikaner	Jaiselmer	Ganganagar	Jodhpur
			EC (dS/m)		
<3.0	32.1	41.7	42.2	60.7	49.0
3.0-5.0	22.9	20.8	23.5	16.7	23.3
> 5	44.9	37.5	34.3	22.6	27.7
			SAR		
<10	23.9	45.8	28.7	73.8	51.8
10-26	49.8	38.2	57.9	20.2	38.9
>26	26.3	16.0	13.4	6.0	9.6
			RSC (me/l)		
<2.5	69.0	81.9	69	86.9	77.4
2.5-5.0	10.1	13.9	11.9	4.8	10.1
> 5	20.9	4.2	19	8.3	12.5

AESR 2.3

This sub-region is better than AESR 2.1 and AESR 2.2 with regard to the irrigation status as more than 34 lakh hectares are under irrigation amounting to 44% of the cultivated area (Table 2.27). This is mainly due to the fact that in Punjab and Haryana, 95 and 71% areas respectively are under irrigation. In Rajasthan only 25% of the area gets irrigated.

Among the sources, contributions from surface water as well as groundwater are equal in Rajasthan portion of the sub-region. On the other hand, there is a dominance of surface water utilization in Punjab and Haryana states as more than 2/3rd of the irrigated area is covered by surface water. In Gujarat, the contribution through surface water is very meagre and groundwater accounts for more than 85% of the irrigated area.

During the decade the irrigated area of the sub-region expanded at a rate of 1.9%. Major contribution for this came from Haryana, which recorded a growth rate of 3.3% followed by Punjab with 0.3%. Source wise also about 3.9 and 4.6% growth were achieved for surface and groundwater sources, respectively at the sub-region level. While in all the states except Haryana there was not much variation between the growth rates from

Table 2.27: Irrigation status of AESR 2.3

States	NIA		Irrigation (%)			Groundwater	
	('000 ha)	per cent of NSA	Canals	Tanks	Ground water	Utilised (%)	Balance (MCM/ year)
Rajasthan	875	22.1	47.9	6.0	46.1	46.9	1088
Punjab	917	94.5	60.6	-	39.4	81.8	650
Haryana	1121	70.7	65.8	0.04	34.1	50.4	1175
Gujarat	520	40.6	11.9	0.3	87.7	30.0	1156
Over all	3433	43.8	52.0	1.6	46.4	52.3	4069
	Decadal Change in area irrigated (%)						
Rajasthan	2.0		9.7	5.6	8.5		-2.5
Punjab	0.3		0.9	-	-0.5		-4.7
Haryana	3.3		1.3	-	9.0		-2.7
Gujarat	1.8		3.7	2.0	1.6		-1.1
Over all	1.9		3.9	1.9	4.6		-2.7

both the sources, in Haryana the growth rate under groundwater contribution was about seven-times more than that of surface water sources.

Surface water resources

In Rajasthan part of the sub-region, the Shekawati, Luni, West Banas and Sukhi are important river basins contributing to the water resources of AESR 2.3. Though presently, Shekawati river basin can meet the water demand, there is a need to adopt water saving devices in this basin on a long term basis. There is one medium and 60 minor irrigation projects in this basin, which need rehabilitation and modernization. In the Luni basin, which drains into Rann of Kutch, most of the river water vanishes into the sandy stretches. It has got 2 major, 9 medium and 344 minor irrigation projects. There is a possibility of at least one more medium and 24 minor irrigation projects in this basin. There is also the possibility of transferring water from Sardar Sarovar Dam and Mahi to this basin in addition to the fact that the capacity of three medium projects can be increased. Conjunctive use of surface water and groundwater needs to be encouraged in this basin.

In the West Banas basin, already 1 medium and 17 minor irrigation projects exist. It is expected that there will be some water left unutilized. As in the West Banas, in this basin also considerable amount of surplus flow exists which can be transferred to the Luni basin. This basin also drains into Gujarat. The groundwater is saline in Shekawati and Luni river basins. The surplus flows existing in many basins need be properly intercepted and utilized. But at the same time there is over draft in the Shekawati river basin. Except in Shekawati river basin wherein by 2015 about 35% decrease is expected in the net water availability, in other basins much reduction in the net availability is not foreseen.

In Punjab, the sub-region is under the command of Bhakra main canal, Sirhind feeder and Eastern canal. In the Sirhind feeder command, though the water resources as per the utilizable values exceed the water requirement of the crops, yet, due to the highly salinised groundwater conditions, the crops do suffer from water shortage. Similarly, in Bhakra main canal and eastern canal systems, water requirement exceeds supply with the highly brackish groundwater conditions further complicating the water resource environment of this region.

Groundwater utilisation

Groundwater utilization is about 52% in the sub-region with a range of 30% in Gujarat to 82% in Punjab. Groundwater balance is around 1100 MCM/year in the states of Rajasthan, Haryana and Gujarat while it is only 650 MCM/year in the Punjab portion. It is around 4000 MCM/year in the sub-region. But, in all cases, the decadal change was found to be negative ranging from 1.1% in Gujarat to 4.7% in Punjab with a sub-regional value of 2.7%. This indicated that in all parts of the concerned states, groundwater was getting depleted in AESR 2.3.

In different districts of Rajasthan, there has been a considerable decline in the undergroundwater balance over a seven-year period ranging from 77 MCM to 313 MCM except in the case of Ganganagar where an increase to the level of 2.2 MCM has been reported (Table 2.28).

In Rajasthan river basins, representing the sub-region, groundwater development is between 80 and 100% and it can be categorized as "dark area". But situation in Shekawati is highly exploited one with a development of over 250% (Table 2.29). In Luni basin, groundwater development is more than 100% indicating mining of groundwater. In West Banas, development is more than 80%. There is a lot of scope for improving groundwater utilization outside the basin, where the development is only 39 per cent.

Table 2.28: Change in groundwater balance between 1983 and 1990

(MCM)

District	Change
Pali	–242.9
Sirohi	–118.9
Sikar	–212.9
Jalore	–313.4
Nagaur	–77.4
Jhunjhunu	–140.7
Churu	–98.5
Jodhpur	–192.5
Ganganagar	+2.2

Table 2.29: Basin-wise groundwater development in Rajasthan part of AESR 2.3

(MCM)

Basins	Draft	Recharge	Development %
Luni	1062	947	112
Shekawati	320	125	254
West Banas	54	67	81
Sukhi	38	48	64
Outside basin	320	828	39
Total	1794	2015	89

A projection for the water supply-demand estimates, made for the relevant basins of the Rajasthan state, showed that, on the sub-region basis there would be 3% decrease in water availability for irrigation. But, in Shekawati basin the situation was critical, since, as high as 35% deficit was estimated in the water availability for irrigation (Table 2.30)

Groundwater salinity status

Saline water occurs in Rajasthan part of the sub-region ranging from 17% in Jhunjhunun to as high as 62% in Jalore district (Table 2.31). Except, Sikar and Jhunjhunun districts, in the rest of the cases the quality of water having SAR of more than 10 varies from 32% in Sikar to 56% in Churu.

The extent of sodic water is less than 25% in districts of Churu, Pali and Jalore while it is more than 50% in Nagaur district. It is between 30

Table 2.30: Basin-wise demand for water

(MCM)

Basin	Total estimated availability	Demand for non-irrigation use		Available for irrigation		Decrease (%)
		1995	2015	1995	2015	
Luni	2117	276	332	1841	1785	3.0
Shekawati	172	68	104	104	68	35.0
West Banas	137	22	28	115	109	5.2
Sukhi	81	7	7	74	74	0.0
Outside basin	4767	268	375	4499	4392	2.4
Total	7274	641	846	6633	6428	3.1

and 40% in other districts. Taking this as an indication, the crop management with saline and sodic water assumes high importance in this sub-region.

AESR 2.4

Physiography and river basins

The physical features of the sub-region are characterized by ranges of hill and isolated peaks by rugged and deeply cut river beds and by well tilled valleys and tracts of rich pasture lands. South Kutch lies in a low fertile

Table 2.31: Groundwater quality in selected districts of AESR 2.3

(% of samples)

Classes	Churu	Pali	Jalore	Nagaur	Sikar	Jhunjhunu
	EC (dS/m)					
<3.0	36.0	56.3	37.6	49.4	73.0	83.1
3.0-5.0	26.9	15.7	21.2	23.4	19.7	12.5
> 5	37.0	28.0	41.2	27.1	7.3	4.4
	SAR					
<10	44.0	52.5	47.3	44.6	67.5	59.7
10-26	46.8	33.0	41.2	42.0	28.7	37.0
>26	9.1	14.4	11.5	13.4	3.8	3.3
	RSC (me/l)					
<2.5	76.0	75.8	78.2	54.8	62.1	53.9
2.5-5.0	6.3	8.5	7.9	12.9	7.6	11.5
> 5	13.4	15.7	13.4	32.3	30.3	27.4

and well cultivated plains behind high bank of sand that lines the sea coast. Beyond this plain, the region is broken by three hill ranges. All the rivers and streams of Kutch starts from its central portion and flow towards the sea in the South and the great Rann of Kutch in the North and the little Rann of Kutch in southeast. The rivers are non-perennial having steep gradients forming deep cuts along their courses and rarely spilling over their banks.

Irrigation Status

Out of the 21 lakh hectares of cultivated lands only less than 4 lakh hectares are irrigated working out to a meagre 18 per cent (Table 2.32). Rainfed farming receives high importance in this sub region. The canal irrigation system accounts for only less than 12 per cent and 87 per cent is through the ground water. There is no area irrigated through major irrigation projects, in the sub region, while 4600 hectares are irrigated through medium and minor irrigation projects, including 5000 hectares through tanks in the Jamnagar district as against 3.7 lakhs of hectares are under irrigation through under ground water.

There are 1.15 lakh wells which are used for agricultural purpose of which 99 per cent is open wells and only 11000 are tube wells which are concentrated only in Surendranagar district. The irrigated area has increased at 2.4 per cent over the decade. Though the canal irrigation is also on the increase by 1.3 per cent, the decadal growth rate for the ground water is more with a figure of 2.6 per cent. The ground water utilization is 32 per cent. The ground water balance is around 453 MCM per year. The ultimate irrigation potential from ground water in this sub region is about 3.83 lakh hectares of which the potential has been created for 1.33 lakh hectares.

Ground water is the predominant irrigation system in this sub-region. As against the annual gross recharge of 1830 MCM, an amount of 435 MCM is utilized for the domestic and industrial purposes leaving only

Table 2.32: Irrigation Status of AESR 2.4

Particulars	NIA		Irrigation (%)			Ground Water	
	'000ha	% to NSA	Canal	Tanks	GW	Use (%)	Balance (MCM/Yr)
Sub-Region	381.6	18.3	11.5	1.5	86.9	32	453
Decadal change	2.4		1.3	3.2	2.6		1.5

1395 MCM utilizable for agricultural purposes. Out of this 942 MCM is utilized for irrigation purposes leaving 453 MCM as the balance. Thus in this region the ground water development is to the tune of 68 per cent (Table 2.33).

Table 2.33: Annual groundwater recharge, draft and development

(MCM/Yr)

Region	Gross Recharge	Domestic & Industrial Uses	Utilizable Recharge for Agriculture	Gross Draft	Balance	Level of Development (%)
AESR 2.4	1830	435	1395	942	453	68

Production Planning and Water Management

Considering the heterogeneity between the North arid zone and other districts of AER 2; with special reference to water resources, irrigation status and physiography, the production planning strategies have to be regionally differentiated. Major strategic interventions are needed in the following areas:

- Drainage coupled with scientific water management practises for the North arid part (Ganaganagar district).
- Development of water use planning models by internalising the inter and intra-basin water transfers within and across AESRs.
- Development of less water demanding and economically viable cropping system.
- Adoption of water saving techniques like drip irrigation, pitcher technology, mulching etc. for all the regions.
- Formulation of suitable irrigation plan for West arid part.
- Development of grassland/pastures in West arid portion.
- Appropriate rain water management progammes with special reference to *in situ* moisture harvesting and efficient utilization through adoption of mulching etc.
- Soil salinity/sodicity and calcareousness leading to nutrient imbalance. Reclamation of saline and sodic soils in the rainfed situations through salinity/sodicity management progammes.

- **Optimum use of poor quality water with special emphasis on conjunctive use.**
- **Stabilization of sand dunes.**
- **Nutrient management with special reference to organic matter, phosphorus and zinc and overcoming deficiencies of nitrogen, phosphorous, zinc and iron.**
- **Wasteland management.**
- **Management of drought conditions at the grain formation stage leading to the grain sterility.**

III. Resource Analysis for Sustaining Water-Food Security in AER 4

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Introduction

The Agro-ecological region 4 (AER 4) known as 'northern plain and central highlands including Aravallis, hot semi-arid ecoregion' comprises 71 districts from six major Indian states viz. Punjab (6), Haryana (10), Rajasthan (14), Gujarat (5), Uttar Pradesh (31) and Madhya Pradesh (5).

The region with an area of 34.9 M ha represents 10.6% of the total area of the country and is home to one out of every six Indians. It has hot and dry summers and cool winters, with rainfall varying between 500 and 1000 mm. The rainfall fluctuates from year to year and for most of the months, the mean monthly rainfall is less than the potential evaporation (PE), except during the couple of months of active monsoon season. The length of growing period (LGP) ranges from 90 to 150 days. The possibility of seasonal drought and consequent crop failure once in every 3 to 4 years is very high and a normal phenomenon. Soils are loamy and the terrain is interspersed by sand dunes.

Rainfed farming is common, with intensive cultivation in areas irrigated through tube wells (Balaguru, 2003). Depending upon the moisture availability index this eco-system is sub-divided into: (i) dry semi-arid with a moisture index variation from –50 to –66.6 where the LGP varies between 90 and 120 days with a rainfall of 500-750 mm, and (ii) moist semi-arid wherein the LGP is between 120 and 150 days, rainfall 750-1000 mm and moisture index –33.3 to –49.9. The AER 4 has four Agro-ecological sub-regions (AESRs) namely AESR 4.1, 4.2, 4.3, and 4.4 (Table 3.1).

Climate

The climate of this eco-region is characterized with hot and dry summers with cool winters. The seasonal distribution of rainfall is highly skewed with nearly 90% of the annual rainfall occurring during the monsoon months of July-October. The year-to-year fluctuations as well as spatial variations in actual rainfall across sub-regions or districts are also quite high. Detailed climatic characterization AESR-wise is discussed below:

Table 3.1: Extent of area coverage of AER 4

Particulars	AESR 4.1	AESR 4.2	AESR 4.3	AESR 4.4
Nomenclature	North Punjab Plain, Ganga-Yamuna Doab and Rajasthan Upland, hot, semi-arid eco-sub-region	North Gujarat Plain (inclusive of Aravalli Plains and East Rajasthan Uplands) hot dry semi arid eco sub-region	Ganga -Yamuna Doab, Rohilkhand and Avadah Plain, hot, moist semi-arid eco-sub-region	Madhya Bharat Plateau and Bundelkhand Uplands, hot, moist semi-arid eco-sub-region
Extent:				
-Area (M ha)	13.4	10.0	6.9	4.6
-per cent of AER 4	38.4	28.7	19.8	13.2
-per cent of India	4.1	3.0	2.1	1.4
District coverage*	Amritsar, Firozpur, Kapurtala, Ludhiana, Patiala, and Sangrur of Punjab; Faridabad, Gurgaon, Jind, Kaithal, Karnal, Kurushetra, Panipat, Sonepat, Rohtak, and Rewari of Haryana; Jaipur, Alwar, Sawai-Madhopur, Bharatpur, Dhaulpur, and Dausa of Rajasthan; and Meerut, Ghaziabad, Aligarh, Muzzafarnagar, Bulandshahar, Mathura, Etah, Agra, Mainpuri, Firozabad, and Moradabad of UP.	Ahemadabad, Kheda, Gandhinagar, Mehsana, and Sabarkanta districts of Gujarat; and Tonk, Ajmer, Udaipur, Bhilwara, Dungarpur, Rajasmand, Chittore-garh and Bundi districts of Rajasthan	Budaun, Shahjahan-pur, Farrukhabad, Hardoi, Jaunpur, Jalaun, Raibarelli, Pratapgarh, Unnao, Allahabad, Fatehpur, Varanasi, Etawah, and Kanpur (Rural and Urban) of UP; and Bhind of MP.	Jhansi, Hamirpur, Lalitpur and Banda of UP; and Shivpuri, Morena, Datia and Gwalior of MP.

* Based on 'India: Agro-Ecological Subregions' Map prepared and published by National Bureau of Soil Survey & Land Use Planning (1996)

Table 3.2: Climate and water balance of AER 4

(Rainfall mm; Temperature °C)

Properties	AESR 4.1	AESR 4.2	AESR 4.3	AESR 4.4
Precipitation (P)	647	726	933	867
Actual rainfall during 1990-95				
Annual average rainfall	586	753	673	797
75% probability rainfall	514	595	656	720
Potential evaporation (PE)	1482	1550	1492	1488
P–PE	–834	-824	-559	–621
Storage	165	527	726	837
Actual Evapotranspiration (ET_a)	622	573	721	703
Water deficit (WD)	849	922	758	780
Water surplus (WS)	13	98	198	159
Annual effective rainfall (%)	77	75	68	66
Humidity index (I_h) %	0.9	6.3	13.3	10.7
Aridity index (I_a) %	57.3	59.5	50.8	52.4
Moisture index (I_m) %	–56.4	–53.2	–37.5	–41.7
Mean annual temperature (°C)	25	26	25	26
Maximum	42	40	41	42
Minimum	5	8	8	6
CV in annual rainfall				
Across districts (in 75% probability)	26	13	11	8
Over time (Actual)	14	26	17	18

AESR 4.1

The annual normal rainfall of this sub-region is 647 mm with as low as 2.7 mm during November to as high as 189 mm during July. The actual rainfall, during the period 1990-95 was quite lower than the normal. The variability in rainfall across districts, as measured by co-efficient of variation (CV) for 75% probability rainfall, was also quite high in this AESR. Here monsoon starts from late June and extends up to September. The monsoon rainfall contributes more than 85% of the total rainfall. In all other months, the rainfall is less than 20 mm. Though this sub-region receives some amount of rainfall every month, the annual effective rainfall was found to be 77%, varying from as high as 100% during Nov-December to as low as 66% during July. The annual ambient temperature was found as 25.2 °C. January is the coolest month with temperature going down as low as 5 °C while June is the hottest month when the mercury touches 42.1 °C. In some years the winter temperature drops to as low as 2 °C, coinciding with the northern disturbances.

As against 647 mm rainfall, the PE is 1482 mm, ranging from 1316 mm in Amritsar to 1745 mm in Jaipur. Except that of July and August when rainfall slightly exceeds the evaporation, in all other months (including the other months of monsoon) the evaporation is far higher than the rainfall (Fig. 3.1). This indicates that there is a need for irrigation during all the months of the year, except July-August for optimum crop production. The mean daily evaporation ranged from 1.1 mm per day recorded during December-January to about 7.0 mm per day recorded during May-June. The mean water deficit was also very high and equalled P–PE values except for Etah district. The dry semi-arid bioclimatic nature of the sub-region was revealed by the corresponding values for aridity index (57.3), moisture index (–56.4), and humidity index (0.9).

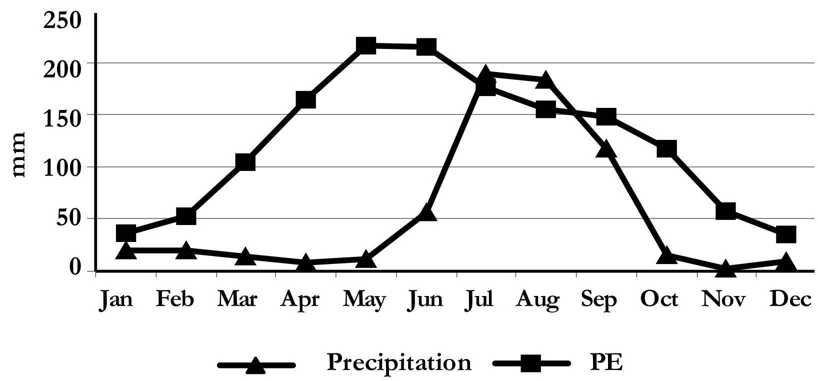

Fig.3.1: Monthly water balance got AESR 4.1

AESR 4.2

The climate of this AESR is hot dry semi-arid, with the mean annual temperature around 26 °C. May and June are the hottest months when the temperature rises as high as 40 °C. On the other hand, January is the coldest month. The soil thermal regime is hyper-thermic as the difference between mean summer soil temperature (MSST) and mean winter soil temperature (MWST) is less than 5 °C. The mean annual soil temperature (MAST) is around 26 to 27 °C. The moisture index of this area varies from –47% in Ahmedabad to – 67% in Ajmer indicating dry semi-arid bioclimatic type. As such the length of growing period (LGP) mostly varies between 90 and 120 days beginning with the last week of June and ending with mid-October.

The mean annual normal rainfall of this AESR is 726 mm, ranging from 520 mm in Bhilwara to 821 mm in Ahmedabad. The monsoon starts from June and practically gets completed by September with very slight rainfall during October. During November to May, the mean monthly rainfall is less than 10 mm. Ninety-five per cent of the total rainfall is received during June to September. Not only the distribution of rainfall is highly skewed but this AESR is also characterized with very high degree of year-to-year rainfall variability as is evident from the corresponding CV values (Table 3.2). The effective annual rainfall is around 75% of the total rainfall. All the rainfall received during non-monsoon months is effective, while only 71% of the monsoon rainfall is effective. The annual PE across districts varies between 1380 mm in Dungarpur to 2144 in Rajkot with an average of 1550 mm for the AESR. Thus it is seen that the total evaporation is almost three-times to that of rainfall. From the Fig. 3.2 it is clear that only during the period July-September, rainfall is either close or higher than evaporation while during rest of the year the evaporation need is much higher than the rainfall. As a result, during most of the period the water deficit is quite large.

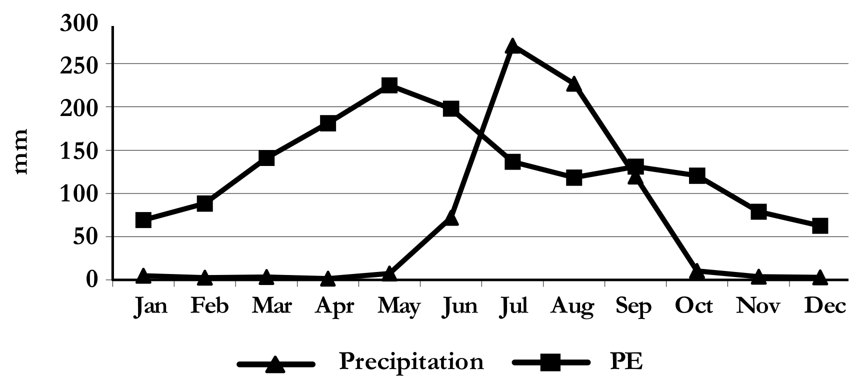

Fig. 3.2: Monthly water balance for AESR 4.2

AESR 4.3

Bioclimatic class of the sub-region is hot moist semi-arid with 25 °C mean annual ambient temperature. During summer months the daily temperature exceeds 40 °C and during winter, it goes down below 8 °C in most of the districts in this AESR. For example, the highest temperature recorded in Fatehpur during June, 2000 was 47.9 °C while the lowest recorded temperature in Etawah was 0.4 °C during January, 1999. The mean annual soil temperature (MAST) is more than 22 °C and the difference between MAST and MWST is more than 5 °C, qualifying it for the hyper-thermic soil thermal regime. The moisture availability period starts from July and ends in November with a LGP of 120-150 days. The moisture index (I_m) which was calculated as the difference between I_h and I_a varied between –33 and –47% across districts, indicating the semi-arid moist conditions prevailing in the sub-region.

The mean annual rainfall in this AESR is 933 mm ranging from 668 mm in Bhind to 1047 mm in Shahjahanpur. This is nearly 60% of the PE. However, the average rainfall received during 1990-95 was substantially lower than the normal rainfall (Table 3.2). The variability of rainfall over time is also quite high with a CV of 17. The monsoon in this AESR sets up during the late June and extends up to the first fortnight of October with 92% of the total rainfall received during this period. The effective rainfall percentage in this AESR is also low as compared to AESR 4.1 and AESR 4.2.

The mean annual evaporation is around 1500 mm, which is about 560 mm more than the precipitation. This AESR represents moderate water deficit zone with some surplus during July and August. However, the evaporation is considerably higher than the precipitation during rest of the year (Fig. 3.3). Although some winter rains are received, the probability of such rainfall is only 30% and *rabi* crops still require supplemental irrigation during critical growth stages such as grain formation stage in wheat. The soil moisture control section (SMCS)

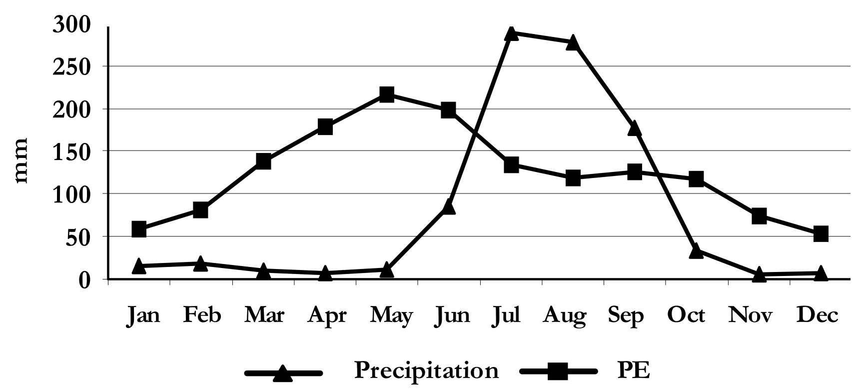

Fig. 3.3: Monthly water balance for AESR 4.3

remains partly or fully dry for more than 90 consecutive days, thus qualifying for the Ustic soil moisture regime. As the SMCS will be moist for 90 to 120 days, it can support single crop of short/medium duration.

AESR 4.4

Climatically this AESR is hot moist semi-arid and falls under strong hyperhermic thermal zone. This sub-region is marked by the extremes of temperature. The mean annual temperature is 25.7 °C with a mean monthly range of 35.5 °C recorded in the month of June and a minimum of 15.3 °C in the month of January. But, in certain days of May and June the maximum temperature raises above 42 °C and the minimum temperature goes below 6 °C in the months of December and January. During summer, high temperature in the plain causes low pressure areas that induce movement of the moonson. Hot breezes locally known as *loo* are common during this period. The moisture availability in the profile starts from the beginning of July and extends up to the second week of November and the soil moisture control section (SMCS) becomes dry from December onwards for more than 90 cumulative days in a year, thus qualifying it as the Ustic soil moisture regime.

The AESR 4.4 receives rainfall of around 700 to 1000 mm in the different parts of the region and the mean annual rainfall is 867 mm (Table 3.2). The intensity of rainfall in this AESR gradually decreases towards west. The monsoon sets in by mid-June and extends up to the first week of October. During this period the sub-region receives 93% of the rainfall. Most of this rainfall is lost to runoff due to such brief and intense nature of rainfall pattern. Therefore, the effective rainfall in this sub-region, particularly during July and August is very low as compared to other AESRs. The winter rains, received between November and February, constitute only 5%. This is useful for cultivation of *rabi* crops but it is usually inadequate without access to supplementary irrigation sources. Moreover, the long-term probability of such winter rainfall is less than 30%.

The mean annual evaporation is around 1488 mm, which is more than 1.7-times of the mean annual precipitation. Except during the months of July-September, the evaporation is more than the precipitation (Fig. 3.4). The mean annual water deficit in the profile is 780 mm and only during July and August some surplus moisture is recorded to the tune of 159 mm. Between October and February, the profile water deficit is 50 mm

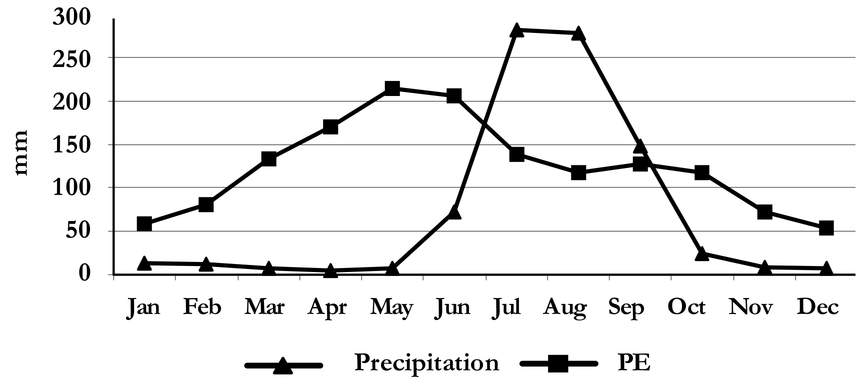

Fig. 3.4: Monthly water balance for AESR 4.4

and less while, it is maximum (202 mm) in the month of May. The available water capacity (AWC) in the profile is good with a value between 150 and 200 mm at 1 m depth of the profile.

Soils

The soils in the AER 4 are diverse and highly heterogeneous across space. Out of 16 major soil types, four are commonly found in this region. Those are alluvium-derived, saline and alkaline, grey brown, and medium and deep black soils. The region is also endowed with the collection of four major soil orders viz. Alfisol, Entisol, Vertisol, and Inceptisol. The dominant soil group is Ustochrept. The potential available water capacity (AWC) of the soils is high, i.e. within the range 150-200 mm/m (Table 3.3). This suggests that crops like sugarcane, cotton, paddy, wheat, etc, can safely be grown. In some pockets where the AWC values are below 150, dry land farming with water harvesting technique is suitable. Detailed AESR-wise soil characteristics are explained below.

AESR 4.1

These soils are basically alluvium-derived and fall under three orders viz, Inceptisols, Entisols and Alfisols. Most of the soils are characterized by Ochric epipedon with or without a calcic horizon. Some of the major groups identified are: Ustochrept-Calciorthids, Ustochrept-Ustipsamments, and Ustochrept-Torriorthents. The saline sodic/sodic soils occur extensively in the low lying areas of Amritsar, Kapurtala,

Table 3.3: Major soils of AER 4

Properties	AESR 4.1	AESR 4.2	AESR 4.3	AESR 4.4
Major soil scapes/type	Alluvium-derived	Grey brown	Loamy alluvium	Mixed red and black
Major soil orders	Inceptisols Entisol Alfisol	Inceptisols Entisol Vertisol	Inceptisols Entisol Alfisol	Inceptisols Vertisol Alfisol Entisol
Dominant soil groups	Ustochrept Natrustalfs	Ustochrept Ustothrent	Ustochrept Ustorthent	Ustochrept Chromusterts
Major land irrigability class*	1 and 3d	2	3d	1 and 3d
Major land capability class*	IIIs	IIs	IIIs	IIe and IIIw
Productivity potential	High	Medium to high	Low, medium and high	Low, medium and high
Soil reaction value (pH)	7.5 - 10.5	8.0-8.1	7.5-10.5	6.6-8.1
Soil nutrient deficiency	Nitrogen Zinc Phosphorus Sulphur	Nitrogen Zinc Sulphur	Zinc Organic carbon	Organic carbon
Major soil series	*Kanjali Zafira viran*	*Navamota*	*Bijapur Hirapur Sakit*	*Singpura*
Available water capacity (AWC) in mm/m	183	154	168	175

* As per FAO standard classification scheme

Sangrur, Patiala, Ferozepur and Gurdaspur districts of Punjab. These soils are sandyloam to clay-loam in texture with soil reaction values varying between 7.5 and 8.5. Major soils in Karnal and adjoining areas of Haryana and considerable areas of Uttar Pradesh are characterized by pH ranging from 8 to 10.5 with salinity from 1 to 60 dS/m and ESP from 30 to 95. The physical and chemical properties of two typifying profiles are discussed below.

Kanjali series (Table 3.4) is the most important and wide spread soil in AESR 4.1. It is a member of fine loamy mixed hyperthermic family of *Typic Ustochrepts* developed on complex material of point bars in the flood plains of Punjab. The soil is well-drained with moderate permeability and usually suitable for cultivation of wheat, rice, sugarcane and lucerne. Acacia species and local grasses are the natural vegetations in such soils. Its irrigability class is 1 with high productivity potentials.

Table 3.4: Important profile characteristics of *Kanjali* series

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	OC (%)	$pH_{2.5}$	$EC_{2.5}$ (dS/m)	CEC
0-22	23.9	56.0	20.1	0.68	7.8	0.75	10.0
22-47	20.9	57.9	21.2	0.27	7.9	0.62	10.5
47-64	24.0	51.2	24.8	0.23	7.9	0.85	10.1
64-77	40.4	38.6	21.0	0.24	7.9	0.61	9.2
77-103	53.8	32.6	13.6	0.12	7.8	0.66	8.1
103-124	53.6	31.1	15.3	0.11	7.9	0.44	8.3
124-140	51.9	37.7	10.4	0.08	7.9	0.65	7.8
140-160	70.7	20.8	8.5	0.08	7.8	0.53	7.7
160-180	73.7	21.0	5.3	0.08	7.8	0.39	7.0

Zarifa viran (Table 3.5) series is a member of fine loamy mixed hyperthermic family of *Typic Natrustalfs*. They have developed on old alluvium in micro-depressions on nearly levelled and flat lands at an elevation of 200 to 250 m. They are imperfectly drained with moderately slow permeability. The land capability class is IIIs with 3d as the irrigability sub class with low productivity potential.

Table 3.5: Important profile characteristics of *Zarifa Viran* series

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	OC (%)	$pH_{2.5}$	$EC_{2.5}$ (dS/m)	CEC
0-5	43.4	34.6	22.0	0.30	10.3	8.2	10.2
5-24	33.4	37.6	29.0	0.30	10.3	8.0	12.8
24-56	30.6	36.2	33.2	0.20	9.8	1.9	14.8
56-85	26.0	42.6	31.4	0.20	9.8	1.4	14.6
85-118	33.2	40.0	26.8	0.10	9.6	1.0	11.2
118-140	45.0	32.0	23.0	0.10	9.2	0.9	9.8

These soils are saline sodic in nature with the presence of both salinity and sodicity in the different sections of the profile. The pH values are also very high but soils can be reclaimed by the application of chemical amendments like gypsum or cultivating the land first with green manure like Daincha (*Sesbania aculeata*) followed by paddy. Provision of field drainage is a must for reclamation of these degraded lands. Apart from the development of saline sodic soil in the canal command areas, saline soils are also developed over a saline water aquifer system. From the fertility point of view, both the normal as well as salt-affected soils are low in nitrogen (N) and medium in phosphorus (P) and sufficient in potassium (K). At some places due to continuous application of P there are tendencies of building up of P reserves in soils. Zinc-deficiency is extensively encountered while in the lighter soils, and sulphur (S)-availability is a limiting factor.

AESR 4.2

The soils are mostly grey-brown type. These soils occur on strong-to-moderately sloping conditions at the foothills of Aravalli ranges and also gently sloping conditions. Inceptisols and Entisols are the major orders identified with Vertisols occurring to a very small extent. Strongly-to-moderately sloping, shallow, gravelly, excessively to well drained foothill soils comprise members of loamy to coarse loamy, mixed, hyper-thermic family of *Lithic Ustorthents*. They occur mostly in Sabarkanta, Mehsana, Ajmer and Udaipur districts.

Soils of *Navamota* series, occurring extensively in this AESR, typified by gently to very gently sloping to nearly level, deep to very deep, calcareous, well to moderately well drained, are a member of fine loamy mixed hyperthermic calcareous family of *Typic Ustochrepts* (Table 3.6). They represent alluvium-derived soils of Sabarmathi flood plains occurring in Sabarkanta, Mehsana, Ahemdabad, Surendranagar districts of Gujarat, and parts of Udaipur and Dungarpur districts of Rajasthan. The clay content is around 13% in the surface and increases to 31% in the sub-surface. The soil reaction is around 8 and does not vary with the depth. The soils are non-saline with very low EC. The $CaCO_3$ content varies between 1.5 and 3%. The organic carbon content is around 0.6% in the surface and gets reduced to 0.3 in the sub-surface. The CEC is 12.5 cmol(p^+) kg^{-1}. Apart from N, they are deficient in Zn and S. The productivity potential of these soils is medium to high and the irrigability class is 2.

Table 3.6: Important profile characteristics of *Navamota* series

Depth (cm)	Clay (%)	$pH_{2.5}$	EC (dS/m)	CEC	$CaCO_3$ (%)	O C (%)
0-25	13.5	8.0	0.14	12.5	1.66	0.63
25-75	21.9	8.0	0.10	—	2.83	0.47
75-100	30.8	8.1	0.13	—	2.26	0.39

AESR 4.3

The soils of AESR 4.3 are basically alluvial with origin from the Ganga-Yamuna flood plains. The dominant orders are Inceptisols, Entisols and Alfisols with Ustochrepts, Ustorthent, Ochraqualfs, Hapludalfs, and Haplustaslfs as the dominant great groups occurring singly or in association. In some pockets the Halaquepts and Natrustalfs are occurring predominantly. The potential AWC of these soils are moderate to high.

Bijapur series is one of the important intensively cultivated soils with high productivity potential and a profile available water capacity of 180-200 mm/m. This is a member of the fine-silty mixed hyperthermic families of *Udic-Ustochrepts*. They occur on gentle slopes of the Ganga upland plains/ alluvial terraces. The soils are nearly neutral with low organic carbon and high CEC. The moisture control section remains dry for more than 90 cumulative days and wet for another 90 or more consecutive days during July to October. The soils are well drained with moderate permeability. While the sand percentage at different depths does not follow any trend, the silt-content gets reduced with the depth and the clay-content tends to increase with the depth (Table 3.7).

Table 3.7: Important profile characteristics of *Bijapur* series

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	$pH_{2.5}$	O C (%)	CEC
0-17	31.2	58.7	10.1	6.8	0.18	5.4
17-32	17.8	60.1	22.1	6.9	0.11	8.6
32-61	15.1	59.9	25.0	6.8	0.15	10.3
61-84	15.0	55.2	29.8	6.7	0.15	12.7
84-119	13.8	54.0	32.2	6.7	0.15	13.6
119-139	12.3	54.4	33.3	6.8	0.12	13.5
139-172	19.2	57.4	23.4	6.9	0.16	12.6

Table 3.8: Important profile characteristics of *Hirapur* series

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	$pH_{2.5}$	EC (dS/m)	OC (%)	ESP	CEC
0-10	65.4	19.6	14.8	10.4	44.4	0.30	96	6.8
10-42	56.9	20.1	23.0	10.3	13.9	0.20	93	9.8
42-71	54.0	20.8	25.2	10.2	3.3	0.20	86	10.4
71-106	50.2	22.6	27.2	9.8	2.1	0.10	82	12.2
106-122	53.0	20.6	26.4	9.7	1.6	0.10	68	10.5
122-150	57.0	22.6	20.4	9.3	1.0	0.10	39	7.8

The *Hirapur* and the *Sakit* series are the other important soil series mostly found in the salt-affected pockets (Tables 3.8 and 3.9). Both the series are imperfectly drained with low saturated hydraulic conductivity in the sub soil. These are saline sodic soils and are strongly alkaline. While the Hirapur series is a member of the fine-loamy, mixed, hyperthermic family of *Aeric Halaquepts*, the *Sakit* series is a member of the fine loamy, mixed, hyperthermic family of *Typic Natrustalafs*. Both the series are deep to very deep, very strongly alkaline with high pH and very high ESP values. The salinity and sodicity tend to decrease with the depth. In the *Hirapur* series the water table is very shallow fluctuating between 0.2 and 2.0 m while in the *Sakit* series, the groundwater table stands at 2 m depth. Both the series need adoption of appropriate soil reclamation techniques and surface drainage for suitable crop husbandry. The land capability class is IIIs and irrigability class is 3d, indicating thereby low production potential due to problems with salinity and inadequate drainage.

Table 3.9: Important profile characteristics of *Sakit* series

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	$pH_{2.5}$	EC (dS/m)	OC (%)	ESP (%)	CEC
11-38	52.4	22.4	25.2	10.4	11.1	0.30	94	12.6
38-48	41.0	25.4	33.6	10.2	8.7	0.30	89	14.1
48-69	41.0	27.4	31.6	10.1	6.5	0.20	89	15.2
69-94	42.8	29.4	27.8	10.0	3.2	0.20	80	12.8
94-121	47.6	25.0	27.4	9.6	1.8	0.10	50	9.0
121-142	50.2	25.2	24.6	9.0	1.3	0.10	28	8.8

AESR 4.4

The dominant orders in this sub-region are Inceptisols, Vertisols, Alfisols and Entisols. The great groups occurring either alone or in association are Ustochrepts, Chromusterts, Haplustalfs, Rhodustalfs and Ustorthents. Among the different series, the *Singpura* and *Itwa* are the important ones.

The *Singpura* series, dominant in this AESR, is a member of the fine loamy, mixed, hyperthermic family of *Typic Ustochrept* (Table 3.10). The surface texture of this series varies from sandy clay loam to clay loam. The sand content in different layers is 50% and above and shows a tendency of decrease within the depth. On the other hand, the clay-content shows an increase with the depth. The soils are neutral in their reaction in the surface layers and tend to become alkaline with the depth. The electrical conductivity values show that the soils are completely non-saline throughout the depth. They are also non-alkaline. They are low in organic matter content which decreases with depth. These soils have good soil moisture and physical properties. The structure is angular blocky at the surface. It can sustain most of the crops both under irrigated and rainfed conditions. The land capability sub class is IIe and irrigability class is 1 with high productivity potential.

Table 3.10: Important profile characteristics of *Singpura* series

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	$pH_{2.5}$	$EC_{2.5}$ (dS/m)	O C (%)	CEC
0-20	59.4	10.8	29.8	7.7	0.2	0.34	17.7
20-32	47.0	17.6	35.4	7.6	0.2	0.21	18.7
32-63	44.9	17.7	37.4	7.5	0.3	0.21	20.2
63-96	42.9	17.6	39.5	7.7	0.2	0.21	21.8
96-116	45.8	16.6	37.6	8.1	0.1	0.20	18.7
116-155	50.7	15.5	33.8	8.1	0.1	0.10	17.8
155-190	50.8	20.5	28.7	8.1	0.2	0.05	14.6

Another series, *Itwa* is a member of the fine, mixed hyperthermic family of Aeric Ochraqualfs (Table 3.11). These soils occur in near level having less than one per cent slope. The soils remain waterlogged during *kharif* season. These are imperfectly drained with poor permeability. The sand percentage is around 10 to 12 in the profile up to 1 metre and suddenly increases to 30 above 1 metre. As against this the silt content varies from

Table 3.11: Important profile characteristics of *Itwa* series

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	$pH_{2.5}$	$EC_{2.5}$ (dS/m)	O C (%)	CEC
0-8	12.4	65.1	22.5	6.6	0.33	0.42	11.6
8-30	9.7	59.9	30.4	6.6	0.37	0.21	13.7
30-81	10.7	50.4	38.9	6.7	0.30	0.21	15.1
81-94	11.9	49.1	39.0	7.7	0.64	0.24	15.7
94-132	32.0	43.2	24.8	7.9	0.54	0.19	9.3

45 to 65% at different depths and decreases with the depth. The clay-content distribution clearly shows the illumination of clay in the B-horizon as seen from the sudden increase in the clay-content in the sub surface horizons and reduction at the last depth. Since they are slow in permeability and imperfectly drained, crops those are resistant to soil salinity and waterlogging are suitable. Further, some appropriate drainage technology should also be adopted to realize better yield. The land capability class is IIIw and the irrigability class is 3d with medium productivity potential.

Much of the Bundelkhand region suffers from acute ecological degradation due to top soil erosion and deforestation, leading to low productivity of the land. Soil erosion is a persistent problem that is aggravated by the hilly landscape, high winds and the poor quality of the soils, leading to the widespread expansion of gullies.

Agriculture and Land Use Pattern

Agriculture is the mainstay of the economy in this region though it is constantly challenged by weather uncertainty. However, the fast growing population with already high population density creates tremendous pressure on the limited land. With less than 11% land area, this region is home to more than 17% population in the country. The flat, fertile and densely populated Ganga-Yamuna doab, one of the most prosperous agriculture regions of India, mostly lies within this AER. Therefore, the region is intensively as well as extensively cultivated. Out of 34.9 M ha geographical area, net area sown is about 22.2 M ha, i.e. 64% of geographical area which is much higher than the national average of 45%. However, compared to other regions in the country, the forest coverage is very low in this region. Nearly equal amount of land is barren and uncultivable (Table 3.12). All these limiting factors coupled with depleting

Table 3.12: Land utilization pattern in AER 4

Particulars	AESR 4.1	AESR 4.2	AESR 4.3	AESR 4.4	AER 4
Reporting area ('000 hectare)	13355	9985	6861	4639	34864
	Distribution (%)				
Forest area	5.2	13.0	2.7	5.2	6.9
Barren & uncultivable land	3.8	11.4	3.5	8.9	6.6
Land under non agricultural uses	8.6	7.2	9.6	7.4	8.2
Cultivable waste	1.5	8.2	2.5	7.7	4.4
Permanent pasture & other grazing land	1.8	6.9	0.5	3.3	4.3
Land under miscellaneous use not included in net sown area	0.3	0.2	0.1	0.3	0.2
Current fallow	2.5	3.5	6.1	3.5	3.6
Other fallow	1.7	3.0	4.1	2.8	2.7
Net sown area	74.6	47.4	69.2	60.9	63.6

Note: Reference year 1995-2000

water resources and associated problems have already raised serious concerns about on the sustainable livelihood security of this region (Natesh et al, 2003)[1] .

Crop husbandry along with dairying is the most dominant economic activity in this region. Due to intensive use of modern seed-fertilizer-irrigation technology, the average productivity of most of the agricultural crops is high. Broad cropping pattern indicates that foodgrains have preponderance in gross cropped area as compared to non-foodgrains (Table 3.13). Cereals alone account for 63% of the gross cropped area, though there are variations across AESRs. Wheat and rice are the leading cereal crops grown mostly in all the districts. Important non-cereal crops are chickpea, pigeon pea, rapeseed and mustard, groundnut, cotton, sugarcane and various fruits and vegetables.

However, inter-district variability in yields for all the major crops is quite high, even within the same AESRs (Table 3.14). And this holds true for all the four AESRs. This clearly demonstrates that though these sub-regions have more or less homogeneous agro-climatic characteristics, in terms of resource position (both natural and physical resources) and thus

[1] This is evident from the fact that in terms of sustainable livelihood security index, out of 52 AESRs in the country, the relative position for AESRs 4.1, 4.2, 4.3, & 4.4 are 43, 48, 41 and 19 respectively.

Table 3.13: Cropping pattern in AER 4

Particulars	AESR 4.1	AESR 4.2	AESR 4.3	AESR 4.4	AER 4
NSA ('000 ha)	9961	4651	4748	2825	22185
GCA ('000 ha)	16363	6075	7068	3282	32798
Cropping intensity (%)	164	131	149	116	148
	Per cent of GCA				
Cereals	68.5	47.6	73.9	42.9	63.2
Pulses	3.4	8.9	11.2	37.0	9.5
Oilseeds	9.0	12.5	4.5	17.0	9.5
Sugarcane	4.8	0.2	2.4	0.2	3.0
Cotton	1.4	4.8	—	—	1.6
Fruit & vegetables	1.9	1.7	2.9	1.6	2.0
Other crops	10.8	24.3	5.1	1.3	11.0
Major cereals	Wheat, rice, pearl millet	Wheat, maize, pearl millet, rice, sorghum	Wheat, rice, pearl millet, maize	Wheat, rice, jowar	Wheat, rice
Major pulses	Chick pea, pigeon pea	Chick pea, pigeon pea	Chick pea, pigeon pea, urd, moong	Chick pea, pigeon pea, moong	Chick pigeon pea
Major oilseeds	Rapeseed mustard, groundnut	Rapeseed mustard, groundnut	Rapeseed mustard, groundnut	Rapeseed mustard, soybean, groundnut	Rapeseed mustard, groundnut

Note: Reference year 1995-2000

adoption of modern farming practices differ quite substantially across and within districts. The cropping intensity for the region is 148% indicating intensive nature of agriculture. The AESR-wise details are discussed below.

AESR 4.1

Land-use

Out of the 13.4 M ha, nearly 10 M ha amounting to about 75% of the geographical area is cultivated (Table 3.12). The major contribution for this AESR comes from Uttar Pradesh. The forest coverage is very less, as only 5.2% area is under forest in the sub-region. And most of the forests are concentrated in the adjoining areas of Rajasthan only. The areas from

Table 3.14: Spatial variability in yield of major crops across districts in AER 4

(CV)

Crops	AESR 4.1	AESR 4.2	AESR 4.3	AESR 4.4	AER 4
Rice	37	40	21	25	40
Wheat	19	32	15	24	30
Sorghum	46	60	27	52	48
Pearl millet	27	75	25	51	39
Maize	27	41	28	39	46
Barley	46	12	27	22	37
Total cereals	25	39	13	21	34
Groundnut	16	36	33	30	29
Sesamum	46	70	30	57	60
Rapeseed mustard	20	26	33	37	31
Total oilseeds	20	32	44	36	34
Chick pea	20	28	18	27	22
Pigeon pea	39	88	33	37	49
Total pulses	33	58	22	12	35
Sugarcane	75	59	25	17	56
Cotton	57	35	NA	NA	55

Note: All calculations are based on average yield during 1995-2000;
NA=Not applicable (as cotton is not grown in AESRs 4.3 and 4.4)

Punjab and Haryana hardly have any forest. The natural vegetation mostly comprises northern tropical thorn forests. Nearly 9% area in this AESR is under non-agricultural use, while barren and uncultivable land constitutes 3.8%. The cropping intensity in this sub-region is 164%, indicating adoption of intensive agriculture.

Area, production and productivity

The principal crops in this sub-region are cereals and oilseeds (Table 3.13). Among the cereals while wheat occupies as high as 37% of gross cropped area (GCA) grown during *rabi* season, rice occupies about 18% of GCA during *kharif* season and grown mostly in the canal command areas of Punjab, Haryana and Uttar Pradesh. In rainfed areas pearl millet, maize, and sorghum occupy considerable proportions. Pulses are grown mainly as *kharif* crops though in some places chickpea is grown in residual moisture during *rabi* season. The major pulse growing pockets are concentrated in UP and Rajasthan parts of this sub-region. Rapeseed and mustard are the dominating oilseed crops contributing to about 8% of the GCA. Sugarcane and cotton are the predominant cash crops grown in Uttar Pradesh and Punjab portions respectively. In the other two states preference to cash crops is low.

The average yields for most of the crops particularly irrigated crops like rice, wheat, cotton and sugarcane, is quite high in this AESR. The productivity of rice is 3 t/ha and that of wheat is 4 t/ha (Table 3.15). However, there is a large variation in yields across districts for most of the crops (Table 3.14). For example, the yield of rice in Punjab and Haryana districts is about 4 t/ha compared to only 1.5 t/ha in Rajasthan districts.

The trends in the area and productivity of different crops indicated substantial change in the cropping pattern in the sub-region. Though the total area under foodgrains remained more or less same, rice emerged as an important *kharif* crop at the cost of *kharif* pulses. However, such a shift was purely based on yield advantage instead availability of water to cultivate rice. In fact rice-wheat cropping system has led to unsustainability of land and water resources in many parts of this region particularly in the regions of Haryana and Punjab (Joshi et al., 2002). The scenario for pulses showed a discouraging trend both in terms of declining area as well as stagnant yield. This may be because of the reason that pulses are now mostly grown in marginal lands. In relatively fertile lands, rice is replacing pulses resulting into fall in total area as well as average productivity of pulses. On the other hand there has been an encouraging trend for oilseeds both in terms of area and productivity growth. The growth in area coverage for rapeseed and mustard is particularly very high. Though the average yield is low, it is increasing at a moderate rate and there exists lot of scope as the difference between actual and potential yields is quite high in this sub-region (Roy and Datta, 2000)

AESR 4.2

Land use

The total geographical area is 10 M ha, two-thirds of which is contributed by Rajasthan and one-third by Gujarat. And because of this, only 47% of the geographical area amounting to 4.7 M ha is put into agricultural use and around 13% of the geographical area is under forest, highest in the AER 4. But most of the forest areas consist of typical thorny shrubs

Table 3.15: Area, production and productivity of major crops in AESR 4.1

(Area '000 ha; Production '000 tonnes; Productivity kg/ha)

Crop	Particulars	Values	Annual average growth rate (%)	Area as % of GCA
Rice	Area	2974	2.7	18
	Production	8801	4.3	
	Productivity	2959	1.6	
Wheat	Area	6057	0.4	37
	Production	23827	2.9	
	Productivity	3934	2.5	
Total cereals	Area	11216	0.4	69
	Production	35648	3.0	
	Productivity	3178	2.6	
Total pulses	Area	563	-8.1	4
	Production	506	-7.9	
	Productivity	899	0.2	
Total foodgrains	Area	11272	-0.1	73
	Production	36232	2.4	
	Productivity	3214	2.5	
Rapeseed mustard	Area	1299	5.9	8
	Production	1421	8.8	
	Productivity	1094	2.9	
Total oilseeds	Area	1479	1.7	9
	Production	1544	4.2	
	Productivity	1043	2.5	
Cotton	Area	223	-2.6	1
	Production	184	1.1	
	Productivity	824	3.7	
Sugarcane	Area	779	-2.8	5
	Production	40828	-0.1	
	Productivity	52422	2.7	
Fruit & vegetables	Area	314	0.7	2

Note: Reference year 1995-2000

commonly found in the desert areas. The encouraging observation was that the forest coverage is increasing in recent decades. Area under barren and uncultivable land is also on higher side. But there are large areas under permanent pasture and cultivable waste category. Area put under non-agricultural use is about 7.2% of the geographical area.

Area, production and productivity

This sub-region grows diverse crops as it experiences wide variation in its soil and water resources. Maize, rice, pearl millet, sorghum, cotton, pulses and groundnut are the major *kharif* crops, while wheat, chick pea and mustard are the principal *rabi* crops in this sub-region. Among the cereals, maize and wheat are the two most extensively grown crops, occupying 14% of GCA during *kharif* and *rabi* seasons, respectively (Table 3.16). Other important cereals are rice, pearl millet, sorghum, and barley. Rapeseed and mustard is the principal oilseed crop in this AESR followed by groundnut and castor. This region has considerable area under cotton and pulses but areas under these crops are fast declining. The production of foodgrain crops in this AESR is nearby stagnant. In fact, the total area under foodgrains is declining at the rate of 1.1% per annum but increasing productivity has helped in maintaining the production level.

The productivity of major crops particularly cotton, pulses, rice and other cereal crops is very low. However, it was interesting to note that in spite of low yield and low yield growth, the area under rice has been increasing over time. Perhaps it is mostly replacing *kharif* pulses and cotton, which have very low yield. Not only the productivity is low in this region but also the spatial variability in productivity across districts are also one of the highest for almost all the crops (Table 3.14). This is because dryland farming is a common practice in this AESR, and *rabi* cropping is also done mainly with limited supplemental irrigation at selected pockets. The region also experiences wide variations in its soil, rainfall and water resources. Further, the agriculture in this AESR is very often challenged by erratic rainfall and frequent dry spells.

A perusal of the growth rates in the Table 3.16 brings out the fact that there is a tendency for bringing more area under oilseed crops at the expense of foodgrains and cotton. The areas under wheat, pulses and cotton are coming down at an annual rate of 0.4, 5.3, and 3.4%, respectively. However, the only encouraging fact was that the yield growth rates for almost all the crops were on the positive side.

AESR 4.3

Land-use

The total geographical area of AESR 4.3 is 6.9 M ha, out of which the net sown area is about 4.7 M ha, i.e. 69% (Table 3.12). Land under non-

Table 3.16: Area, production and productivity of major crops in AESR 4.2

(Area '000 ha; Production '000 tonnes; Productivity kg/ha)

Crop	Particulars	Values	Annual average growth rate (%)	Area as % of GCA
Maize	Area	814	-0.1	14
	Production	942	0.5	
	Productivity	1157	0.6	
Wheat	Area	813	-0.4	14
	Production	1610	1.7	
	Productivity	1980	2.1	
Rice	Area	393	1.6	7
	Production	546	2.8	
	Productivity	1389	0.8	
Total cereals	Area	2889	-0.5	47
	Production	3870	0.5	
	Productivity	1340	1.0	
Total pulses	Area	541	-5.3	9
	Production	336	-4.7	
	Productivity	621	0.6	
Total foodgrains	Area	3430	-1.1	56
	Production	4206	0.2	
	Productivity	1226	1.3	
Rapeseed mustard	Area	567	2.7	9
	Production	587	5.2	
	Productivity	1035	2.5	
Groundnut	Area	133	-0.3	2
	Production	134	1.3	
	Productivity	1004	1.6	
Total oilseeds	Area	762	2.2	12
	Production	741	3.6	
	Productivity	972	1.4	
Cotton	Area	294	-3.4	4
	Production	65	-0.8	
	Productivity	220	2.6	
Fruits & vegetables	Area	105	0.5	2

Note: Reference year 1995-2000

agricultural uses ranked second after net sown area. This is because many industrial and large cities like Kanpur, Allahabad and Varanasi are situated in this AESR. Only 2.7% of the land area is occupied with forests, one of the lowest in the country. The natural vegetation mostly comprises tropical dry deciduous and thorny forests. The fallow and cultivable wastelands together occupy nearly 13% of the geographical area, which is the potential source to meet future requirements in terms of additional croplands and residential areas.

Area, production and productivity

This sub-region is a fertile one with a cropping intensity of around 150%. Although dryland farming is the traditional practice, the region is moderately endowed with water resources and the resource rich farmers have the capacity to overcome seasonal water deficiency through providing supplementary irrigation. As a result, water-consuming crops like rice-wheat in sequence and sugarcane are dominant in this zone. The average yield level for major crops is also moderately high with relatively lower variability across districts (Tables 3.14 and 3.17).

Cropping pattern in this sub-region is dominated by foodgrains (Table 3.17). The area under foodgrain is more or less stagnant but yield growths along with some small changes in cropping pattern are the principal source for additional production of foodgrains in this AESR. Wheat is the single most predominant *rabi* crop in this sub-region, occupying an area of 2.8 M ha with average productivity of 2.8 t/ha. Rice is the major *kharif* crop grown in 22% of GCA with average productivity level of more than 2.1 t/ha. Maize, pearl millet and sorghum are the other cereal crops grown in this sub-region. The average productivity of pulses is more than 1.1 t/ha. Among the oilseed crops, which contribute to 5% of the net cultivated area, mustard and groundnut are the important ones, but their productivity levels are not high. Since the sub-region is endowed with enough water resources, sugarcane and potato are grown in most of the districts as cash crops. The mean productivity of these crops is also on higher side when compared with average productivity level in the AER.

AESR 4.4

Land use

The sub-region has a geographical area of 4.6 M ha with more or less equal contribution from only two states, viz. Uttar Pradesh and Madhya Pradesh. The net sown area accounts for 61% of the total geographical area while forest area constitutes only 5.2%. This region was earlier densely forested.

Table 3.17: Area, production and productivity of major crops in AESR 4.3

(Area '000 ha; Production '000 tonnes; Productivity kg/ha)

Crop	Particulars	Values	Annual average growth rate (%)	Area as per cent of GCA
Rice	Area	1551	1.0	22
	Production	3275	4.7	
	Productivity	2112	3.7	
Wheat	Area	2783	0.8	40
	Production	7733	2.9	
	Productivity	2778	2.0	
Total cereals	Area	5222	0.3	74
	Production	12277	2.7	
	Productivity	2351	2.4	
Total pulses	Area	793	-1.7	11
	Production	882	-1.1	
	Productivity	1112	0.6	
Total foodgrains	Area	6015	-0.1	85
	Production	13159	2.6	
	Productivity	2188	2.6	
Rapeseed mustard	Area	213	3.8	3
	Production	221	7.0	
	Productivity	1038	3.2	
Total oilseeds	Area	316	2.4	5
	Production	275	5.0	
	Productivity	871	2.6	
Sugarcane	Area	167	0.1	3
	Production	9005	3.4	
	Productivity	53838	3.3	
Fruits & vegetables	Area	200	0.6	3

Note: Reference year 1995-2000

Post-independence population growth and the emergence of green revolution brought larger tracts of land under cultivation that led to increasing levels of deforestation. The more alarming observation is that the forest cover was dwindling down at a very fast rate due to government approved large scale commercial logging, combined with poor land management. Considerable land area (8.9%) is also barren and under uncultivable category. But the area under fallow and cultivable waste put together is as high as 14% of the geographical area where cultivation is possible.

Area, production and productivity

Due to predominantly rural population and lack of off-farm income sources, agriculture plays an important role in this AESR. The poor soils and uncertain rainfall have made agriculture risky in this sub-region. With very limited irrigation facilities, a very low proportion of net sown area is cultivated more than once resulting in lower cropping intensity. Average crop productivity is one of the lowest in the country. Frequent drought and floods also destroy crops. The farmers practice mixed cropping as a precautionary measure against crop failure. Cereals, pulses and oilseeds are the only major crop groups in this sub-region, together accounting for as high as 97% of the gross cropped area (Table 3.13). Fruits, vegetables, and fibre crops are only secondary in importance and are highly localized. In Uttar Pradesh districts of this sub-region, pulses are the major crops with almost 50% of the GCA. While in Madhya Pradesh portion, cereals and oilseeds are principal crops but foodgrains are slowly giving way to oilseed crops.

Among the cereals, wheat is the single most important crop grown during the *rabi* season throughout the sub-region occupying nearly 30% of the area. Rice and sorghum are the important *kharif* cereals. The important pulse crop grown during *rabi* is chick pea which is grown in about 25% of the area. Pigeon pea is grown mainly on the rice bunds. The rapeseed and mustard followed by groundnut contribute to the bulk of the area under oil seed crops group, which occupy 17% of the GCA. Soybean is another *kharif* oilseed crop.

The productivity figures for almost all the crops, except wheat, are around 1 t/ha, which is certainly on the lower side. Even for wheat the productivity is marginally above 2 t/ha. A perusal of growth rates in Table 3.18 points to the shift in the cropping pattern in favour of oilseed crops. The foodgrains are definitely giving way to oilseed crops in this AESR. However, in spite of the fact that the area under foodgrains was reducing, the productivity growth rates were quite high, especially for rice and wheat. Higher growth rate was recorded in production for major oilseed crops.

Livestock Resources

As elsewhere in the country, livestock in this AER is closely integrated with crop-raising activities. Livestock is considered as a source of food, fuel, manure, draught power, ready cash in emergency, a movable asset

Table 3.18: Area, production and productivity of major crops in AESR 4.4

(Area '000 ha; Production '000 tonnes; Productivity kg/ha)

Crop	Particulars	Values	Annual average growth rate (%)	Area as per cent of GCA
Wheat	Area	962	0.2	29
	Production	2121	3.4	
	Productivity	2204	3.1	
Sorghum	Area	155	-1.1	5
	Production	125	1.2	
	Productivity	807	1.9	
Rice	Area	130	-2.5	4
	Production	175	1.7	
	Productivity	1343	4.2	
Total cereals	Area	1408	-0.6	43
	Production	2621	2.3	
	Productivity	1861	2.9	
Total pulses	Area	1213	-0.7	37
	Production	1105	-0.2	
	Productivity	911	0.5	
Total foodgrains	Area	2621	-0.7	80
	Production	3726	1.1	
	Productivity	1421	1.8	
Rapeseed mustard	Area	277	3.2	9
	Production	262	6.9	
	Productivity	945	3.7	
Groundnut	Area	117	2.5	3
	Production	116	5.7	
	Productivity	989	3.2	
Total oilseeds	Area	559	2.9	17
	Production	464	5.5	
	Productivity	831	2.6	

Note: Reference year 1995-2000

and an investment option. And because of frequent crop failure in this region, livestock rearing occupies an important position in this part of the country and constitutes the major source of food, income and employment to the rural households. Further, apart from its great popularity and acceptability in this region, dairy products particularly milk, is recognized as a nutritive food *par excellence*. Milk provides 95%

of animal protein and almost 100% of animal fat in the daily diet of an average Indian in the arid and semi-arid regions (Roy et al., 2002). Semi-arid agriculture also contributes a major fodder resource in the form of crop residues as well as oilseed and pulse by-products that constitute an important feed to the dairy animals.

The total number, composition and density of livestock population in AER 4 is given in Table 3.19. It includes cattle, buffalo, sheep, goats, horses, mules, donkeys, and pigs. The total number of livestock population in this region as per 1997 census was 80 million. The livestock densities are quite high though there are considerable variations across AESRs. While the all India average is around 40 tropical livestock unit (TLU) per square kilometre of geographical area, densities in AER 4 range from 88 TLU in AESR 4.2 to 163 TLU in AESR 4.3.

Table 3.19: Livestock resource in AER 4

Particulars	AESR 4.1	AESR 4.2	AESR 4.3	AESR 4.4	AER4
Total livestock population (million)	28.0	22.0	21.9	7.7	79.7
	Distribution of livestock population (%)				
Cattle	21.9	31.5	36.3	49.4	31.2
Buffalo	51.2	17.9	26.1	20.4	32.1
Sheep	8.5	20.1	4.4	4.4	10.2
Goat	14.6	29.9	18.1	19.5	20.3
Pig	3.5	0.5	14.4	5.9	5.9
Horses and others	0.3	0.1	0.8	0.4	0.4
Livestock density[2] (TLU/sq km)	115	88	163	89	113

Note: Reference year 1997

The cattle and buffalo each contributes to nearly one-third of the total livestock population in this region. However there is a considerable variation in the composition of livestock population across AESRs. While it is buffalo, which is dominant in AESR 4.1, small ruminants occupy a very important position in AESR 4.2. Cattles, mostly indigenous breeds, and goats are dominant livestock species in AER 4.4.

[2] A tropical livestock unit (TLU) is the common unit for describing livestock numbers of different species. It is used to aggregate different classes of livestock regardless of the specific composition. One TLU equals an animal of 250 kg live weight. On an average TLU values are Camels/Horse= 1.0; Cattle= 0.7; Sheep/Goats= 0.1; Pig=0.3.

Small ruminants, particularly sheep and goat are important species in the agricultural economy of this semi-arid region, where marginal and sub-marginal lands are less dependable for agricultural production. These are perhaps the most appropriate livestock species for utilizing the sparse vegetation available or expected to be available in such areas through rangeland and pasture development. They can survive on extremely poor and low vegetation because of their close grazing habits and ability to travel over long distances to obtain sufficient forage and water to subsist.

Land Holdings

India is a land of small farm holdings and this region is no exception. The total number of operational holdings as per 1995 census was more than 15 million. About 61% of them were of less than one hectare in size and only 0.9% of the working farms encompassed ten or more hectares of land (Table 3.20). The average size of holding in this region is only 1.37 ha. High dependence on agriculture and very high density of population in this region are factors such a small size of holdings. Over the last seven

Table 3.20: Distribution of operational holdings across size groups in AER 4

Particulars	AESR 4.1	AESR 4.2	AESR 4.3	AESR 4.4	AER 4
Total number of holdings (million)	5.2	2.6	6.4	1.5	15.7
	Distribution of holding numbers (%)				
Marginal (< 1 ha)	55.9	41.0	77.0	45.3	60.9
Small (1-2 ha)	20.7	25.1	14.3	25.9	19.4
Semi-medium (2-4 ha)	14.8	20.2	6.5	17.7	12.7
Medium (4-10 ha)	7.5	11.7	2.1	10.1	6.3
Large (>10 ha)	1.0	1.9	0.1	1.6	0.9
	Distribution of operated area (%)				
Marginal (< 1 ha)	16.0	9.4	35.9	11.5	18.3
Small (1-2 ha)	19.4	17.1	25.0	19.8	20.2
Semi-medium (2-4 ha)	27.1	26.8	22.2	25.7	25.7
Medium (4-10 ha)	28.1	32.7	14.6	30.3	26.4
Large (>10 ha)	10.0	14.0	2.6	12.6	9.7
Average size of holding (ha)	1.53	2.11	0.79	1.92	1.37
CV in average holding size (across districts)	32	31	33	21	31

Note: Reference year 1995

years, the average size must have reduced further, and continue to decline in the coming years. The predominance of small farms has an implication in terms of their livelihoods as it is this group which has to bear the brunt of adjustments through petty non-agricultural occupations and migrations (Jha, 2001).

A perusal of the Table 3.20 clearly indicates that there is high degree of disparity and inequality in the distribution of landholdings in all AESRs. The distribution of cultivable land is also highly skewed across households as well as over space as is evident from the corresponding distribution pattern of operated area across size groups and high CV values across districts.

Water Resources and Irrigation

The association between water resources and development pattern is ancient. Water resource has been the most important factor governing the distribution of man around the world and India is no exception. Water is perhaps the most critical natural resource in this part of the country. High population growth, expansion of irrigated land, low rainfall, and recurring droughts exacerbate water scarcity in this region. The water resource in this AER is not only scarce but has highly uneven distribution both in time and space.

There is a considerable variation in the per cent net sown area irrigated across AESRs in this region. Even within the AESRs there exists a high degree of variability across districts as is evident from the corresponding CV values (Table 3.21). Geographically, the area lies in the Ganga-Yamuna doab region i.e., AESRs 4.1 and 4.3 have considerably high proportions of irrigated area. The major irrigation systems in the regions are tubewells, canals, and other wells. Groundwater becomes the major source of irrigation in virtually all the areas in this region. Irrigation water requirements for the second season are mostly met through groundwater resources and partly through canals. Because of semi-arid climate, tanks have very limited presence in this AESR.

The groundwater resources and irrigation potential (both due to natural recharge as well as recharge augmentation from the canal system) during 1995 are furnished in Table 3.22. It is evidenced that the stage of groundwater development varies widely across AESRs. The level of groundwater development is very high in AESR 4.1 as compared to that

Table 3.21: Irrigated area in AER 4

Particulars	AESR 4.1	AESR 4.2	AESR 4.3	AESR 4.4	AER 4
Gross irrigated area ('000 ha)	10.5	2.6	4.6	0.7	18.4
Net irrigated area ('000 ha)	6.5	2.2	3.2	0.7	12.6
Per cent area irrigated	65	47	68	20	56
Irrigation intensity (%)	162	120	141	109	146
	Source wise distribution of irrigated area (%)				
Canals	16.9	17.9	35.2	47.7	23.4
Tanks	0.2	7.3	0.3	1.9	1.5
Tube wells	68.4	23.4	61.9	10.6	55.9
Other wells	13.9	50.7	0.7	27.8	17.6
Other sources	0.5	0.7	2.0	12.0	1.6
CV in irrigated area (Across districts), %	20	27	22	32	28

Note: Reference year 1995

Table 3.22: Groundwater perspectives in AER 4

(MHM)

Particulars	AESR 4.1	AESR 4.2	AESR 4.3	AESR 4.4	AER 4
Total replenishable groundwater resource	3.43	0.67	2.26	0.79	7.14
Provision for domestic, industrial & other uses	0.47	0.10	0.34	0.12	1.02
Available groundwater resource for irrigation in net terms	2.96	0.57	1.92	0.67	6.12
Utilisable groundwater resource for irrigation in net terms	2.66	0.51	1.73	0.61	5.51
Gross draft estimated on prorata basis	3.34	0.45	1.00	0.19	4.98
Net draft	2.34	0.32	0.70	0.13	3.48
Balance groundwater resource for future use	0.62	0.25	1.22	0.54	2.64
Groundwater development (%)	97	68	44	24	70

Note: Reference year 1995

in AESR 4.3 or AESR 4.4, implying the scope for further groundwater development in these two AESRs. However such scopes are quite location-specific, as even in AESRs 4.3 and 4.4, based on the status of groundwater development, quite a few blocks have been characterized as overexploited or dark (Table 3.23).

Table 3.23: Status of groundwater table in AER 4

Particulars	AESR 4.1	AESR 4.2	AESR 4.3	AESR 4.4	AER 4
Total number of blocks	442	156	252	82	932
Block overexploited or dark (%)	22	14	15	6	17
Block grey (%)	43	34	25	10	34
Block white (%)	35	52	60	84	49

Note: Reference year 1995 (for AESRs 4.1 & 4.2) and 1998 (for AESRs 4.3 & 4.4)

Groundwater plays an important role in both agriculture and drinking water supply in this region. However, a critical issue facing many groundwater aquifers in this region is that the volume of water withdrawal exceeds long term recharge, resulting in rapidly declining groundwater levels. Out of 71 districts in this AER, in as many as 47 districts groundwater table is falling more than 20 cm per year (Table 3.24). The over-exploited/dark blocks are concentrated mainly in Haryana, Punjab, Gujarat and Rajasthan parts i.e. in AESRs 4.1 and 4.2. Permanent depletion of groundwater aquifer as in the case of Mehsana district in Gujarat and increase in the number of stressed groundwater blocks in these regions signal the disturbing trends emerging in the groundwater sector.

Table 3.24: Districts with water table fall more than 4 m during last two decades

AESR	Name of districts
AESR 4.1	Faridabad, Gurgaon, Kaithal, Kurukshetra, Panipat, Rewari, Amritsar, Ferozepur, Kapurthala, Ludhiana, Patiala, Sangrur, Alwar, Jaipur, Agra, Aligarh, Bulandsahar, Etah, Ghaziabad, Mathura, Meerut, and Moradabad
AESR 4.2	Ahmedabad, Kheda, Mehsana, Sabarkantha, Bhilwara, Chittoregarh, Dungarpur, Rajasmand, and Udaipur
AESR 4.3	Bhind, Allahabad, Badaun, Etawah, Farrukhabad, Fatehpur, Hardoi, Kanpur, Lucknow, Rai bareli, Shahjahanpur and Unnao
AESR 4.4	Datia, Gwalior, Morena, and Shivpuri

Note: Reference year 1981-2000; Source: www.water-mgmt.com

Lack of comprehensive policies to guide groundwater development and use in a sustainable manner has resulted in over-exploitation of this resource in varying magnitudes at several locations in this region. Since groundwater is a common property resource with individual benefits and collective costs, the issue of managing groundwater becomes vital. Depletion of groundwater resource also has serious equity implications since falling water tables take water out of reach of small and marginal farmers. Moreover, it makes wells for domestic water supply run dry. Besides the falling groundwater table, in several pockets of AESRs 4.1 and 4.3, rising water table due to waterlogging and poor drainage is also a serious problem.

Since water-related issues are highly localized ones, scenarios at aggregate level have the potential to mask the wide variability at disaggregated level. Statistics in the form of aggregated information at macro level mask issues of local water scarcity. This is especially true when vast spatial and seasonal variations exist in terms of the factors that determine water supply and demands. However, knowledge of micro level water resources is very important. Therefore details of water-related issues have been discussed at AESR level and also at basin level wherever information was available.

AESR 4.1

River basins and water resources

Physiographically the whole sub-region falls under alluvial plains. In Rajasthan part of this AESR, Ruparail, Banganga, Gambhiri, Parvati and Sabi river basins serve this region. In these basins totally two major, 17 medium and more than 380 minor irrigation projects are functioning. Still there is a scope of increasing the storage capacity of medium irrigation projects as well as construction of at least 20 more new minor projects. This will go in a long way for increasing the utilization of the potentials. However, one of the major problems encountered in most of the projects is lack of adequate drainage outlets.

In the Rajasthan part of the sub-region, reported total water availability is about 4267 MCM. Out of this nearly two-third have been reported to be in the Banganga basin, and the rest in the remaining four basins. On an average, groundwater contributes to 45% of the total available water (Table 3.25).

In the river basins of Rajasthan falling under this sub-region, it is estimated that by 2015 the water requirement for non-irrigation purposes will increase from 307 MCM to 487 MCM thereby reducing the availability

Table 3.25: Total water availability in the Rajasthan region of AESR 4.1

(MCM)

Basins	Groundwater	Surface water	Interstate basin	Total
Ruparail	150	138	-	288
Banganga	1112	581	1119	2812
Ghambiri	383	232	-	615
Parbati	121	157	-	278
Sabi	175	99	-	274
Total	1941	1207	1119	4267

for irrigation water by 4.5% (Table 3.26). Considerable intra-basin variations were observed and in Ruprail basin the decline would be as high as 24% followed by 10% decrease in Sabi basin. This implies that substantial improvement is required in the water-use efficiency in these two basins to manage this deficit.

The Punjab area falling under the influence of Ravi, Beas, and Sutlej river systems is irrigated through Bhakra command. Ravi-Beas, Bhakra and Yamuna are the major systems in Haryana. Though Bhakra Canal system is a major system occurring in this sub-region its major influence is mostly in Punjab and Haryana only. In the Rajasthan part the irrigation is only through minor irrigation projects followed by medium irrigation projects and a couple of major irrigation projects.

Table 3.26: Basin wise estimated change in water demand by 2015

(MCM)

Basins	Estimated availability	Sectoral demand/availability				Change in water availability for irrigation, %
		Non-irrigation		Irrigation		
		1995	2015	1995	2015	
Ruprail	288	75	125	213	163	-23.5
Banganga	2812	118	189	2694	2623	-2.6
Ghambiri	615	44	69	571	546	-4.4
Parbati	278	21	32	257	246	-4.3
Sabi	274	49	72	225	202	-10.2
Total	4267	307	487	3960	3780	-4.5

Source: Acharya (1998)

Irrigation

A major part of this sub-region being in the Gangetic basin, this AESR represents a heavily irrigated zone with 65% of NSA under irrigation (Table 3.21). This is mainly due to extensive canal system network developed in Punjab part of this region. However, in Rajasthan part only 45% of NSA is under irrigation. At the sub-region level, a decadal growth rate of 13% has been registered in the net irrigated area. But in Punjab and Haryana state where already 95 and 82% of NSA is under irrigation, the decadal growth rate has been minimum. Source-wise, the sub-region is predominantly irrigated through groundwater and tank irrigation is negligible. Canal irrigation contributes to 17%, mostly concentrated in the Punjab part. In Haryana part, the contribution by both the sources is almost same.

Groundwater

Groundwater utilization is of the order of 65% in this sub-region. It is almost 100% in the Haryana part and as low as 45% in UP part. Though at the sub-region level almost 9000 MCM groundwater is available as a balance, it is depleting at a very fast rate particularly in Haryana part where the balance has become extremely low (Table 3.27).

Table 3.27: Groundwater balance in AER 4

AER/AESR/Zones	Utilization, %	Balance MCM/year	Annual change in balance, %
AESR 4.1	65.4	8954	-8.3
UP part	45.0	6689	1.5
Punjab part	81.8	655	-4.7
Haryana part	99.6	17	-25.2
Rajasthan part	55.7	1593	-4.6
AESR 4.2	47.3	2851	-1.9
Gujarat part	45.1	1498	0.2
Rajasthan part	49.6	1353	-3.9
AESR 4.3	41.1	12822	0.6
AESR 4.4	20.0	6340	-1.9
MP part	15.7	3669	-0.4
UP part	24.3	2671	-3.3
AER 4	44.4	30967	-2.7

Note: Reference years 1983 and 1990

The situation in the Punjab and Rajasthan parts are also discouraging as in both the situations the groundwater balance has been declining. On the other, hand in UP part the balance is increasing quite substantially.

There has been a fall in the groundwater table to the tune of 0.1 to 0.2 m per year in the Punjab part of this sub-region during a period of 24 years (year ending 1998). The problems in districts of Haryana part is more severe as there has been a fall in the water table ranging from 1 m (in Sonepat) to 10 m (in Kurushetra) during the same period. However, during the corresponding period in Jind and Rohtak districts, there has been a rise in the water table from 3 to 7 m mostly because of waterlogging due to inadequate drainage and lower extraction of groundwater. Groundwater exploitation is a disturbing factor in the Rajasthan part of the sub-region too. In all the basins, except Banganga, the groundwater development is more than 100%, ranging from 101% in Gambhiri to as high as 334% in Sabi indicating that all these basins are over-exploited (Table 3.28). Even in Banganga, the groundwater development is to the tune of 90%. In the Uttar Pradesh, a tendency for the increase in the groundwater balance was observed which might be mainly due to the high recharge in the Gangetic plain as the perennial rivers flooding large areas are common during rainy seasons.

Table 3.28: Basin-wise groundwater development in Rajasthan part

(MCM)

Basins	Draft	Recharge	Development %
Ruparail	295	150	197
Banganga	1006	1112	90
Gambhiri	388	383	101
Parbati	145	121	120
Sabi	526	158	334

Groundwater quality

Water quality for irrigation refers to the kind and amount of salts present in it and its effects on crop growth and development. Salts are present in variable concentrations in all waters and these influence osmotic pressure of the soil solution: higher the concentration, greater the osmotic pressure. Osmotic pressure in turn affects the ability of plants to absorb water through their roots.

The chemical properties of groundwater for selected districts in this AESR show that based on the salinity criteria, the waters from Aligarh, Firozabad and Etah districts do not pose any salinity problem (Table 3.29). But, the waters from Agra and Mathura indicate high salinity as 20-35% of the samples from these two districts recorded salinity of more than 5 dS/m. The sodium adsorption ratio (SAR) values, which indicate the predominance of sodium over calcium and magnesium, are also high (>10) particularly in Agra and Mathura. More than 50% of the samples from the Aligarh and Firozabad districts had high residual sodium carbonate (RSC) level, which indicated the alkalinity level of the water. Thus while in Agra and Mathura, salinity is widespread, in the districts of Aligarh and Firozabad alkaline water occurrence is extensive.

Table 3.29: Groundwater quality in selected districts of AESR 4.1

(% of samples)

Properties	Agra	Mathura	Aligarh	Firozabad	Etah
EC (dS/m)					
<3.0	52.6	59.2	93.3	92.4	97.4
3.0-5.0	11.1	19.2	4.2	4.4	2.6
> 5	35.6	21.5	2.5	3.2	0.0
SAR (ratio)					
<10	57.6	69.2	81.6	83.3	88.7
10-30	40	30.1	18.1	16.5	11.3
>30	2.4	0.6	0.4	0.2	0.0
RSC (me/l)					
<2.5	70.8	70.7	49.8	46.4	74.8
2.5-5.0	13.9	13.9	28.9	33.3	18.3
> 5	15.4	15.3	21.2	20.5	6.9

Source: Acharya (1998)

AESR 4.2

River basins and water resource

The major river basins in this sub-region are: Banas, Mahi and Sabarmati. Banas is the largest basin with an estimated water availability of 6000 MCM followed by Mahi with availability of 3300 MCM, and Sabarmati which is the smallest one. In Banas basin, around 3400 MCM is available as surface water and 2200 MCM are estimated to be available as groundwater through recharge. The corresponding figures for the Mahi basin are 2900 MCM and 400 MCM. Put together in all the three basins of Rajasthan state, there are 10 major, 82 medium and 1490 minor irrigation projects. In Gujarat part of this AESR, 25 major and medium projects are currently in operation.

Irrigation

In this AESR, out of 4.7 M ha of NSA, only 2.2 M ha (47%) receives irrigation (Table 3.21). The percentage of irrigated area to net sown area is higher in Rajasthan part as compared to that in Gujarat portion. At the AESR level, net irrigated area is expanding at an annual growth rate of 1.4%. Basically, groundwater irrigation dominates in the sub-region as 75% of the irrigation is through groundwater as against 18% from canal. There is not much variation between the two states in this aspect, except for the fact that though, at the AESR level tank irrigation system contributes around 7% to the net irrigated area, for all practical purposes, tank irrigation can be treated as negligible for the Gujarat part.

Groundwater

The groundwater development was to the tune of 94% at the sub-regional level while it was more than 100% in Rajasthan and 88% in Gujarat part (Table 3.30) But within Gujarat, the utilization in Gandhinagar and Mehsana was 116 and 132%, respectively.

Though at the sub-region level, about 2850 MCM groundwater was available as a balance, it was depleting at an annual rate of 1.9% per annum (Table 3.27). The situation was particularly critical in Rajasthan

Table 3.30: Groundwater development pattern in AESR 4.2

District/River basin	Development %
Gujarat	88
Ahmedabad	74
Gandhinagar	116
Mehsana	132
Sabarkantha	71
Surendranagar	56
Rajasthan	102
Banas	102
Mahi	100
Sabarmathi	113
AESR 4.2	94

part of this sub-region where the rate of depletion was around 4% per annum. In fact, except for Bundi and Udaipur, in all other districts there had been a sharp decrease in groundwater balance to the tune of 103 MCM in Tonk to 374 MCM in Chittoregarh district during the period 1983 to 1990. Thus in this sub-region, prime objective for sustainable water management should be to check and reverse the depleting water table in these districts.

AESR 4.3

River basins and water resource

Being in the Gangetic Plains, there is a good network of rivers in this AESR. The sub-region is intersected by the Yamuna and its southern tributaries like Chambal and the Ganga and its northern tributaries such as Ram Ganga, Gomati, Ghagra, etc. There is also a well developed canal irrigation network in this sub-region except in Badaun, Farrukhabad and Shahjahanpur districts. The important irrigation projects in this sub-region are Kishanpur canal system, Yamuna canal system, Urmil dam, Meja dam, Bansagar dam, Tehari dams, Sharada sahayak project, Gyanpur canal system, Chambal project and Jarauli project.

Irrigation

This AESR is one of the highly irrigated areas in the country as more than two-thirds of the NSA is irrigated with an irrigation intensity of 141% (Table 3.21). Being situated in the Indo Gangetic Plains, the area is characterized with large canal network. But ironically only 35% of the irrigated area receives water from the canal system. Ground water, mainly through the shallow tube wells, is the dominant source of irrigation. During the last two decades, there has been a considerable increase (at the rate of around 6% per annum) in the net irrigated area through groundwater. Area irrigated with canal water has also increased at the rate of 3% per annum during this period.

Ground water

There has been a trend of increasing groundwater balance in most of the districts in this AESR. During 1995, the groundwater balance in the sub-region was 12822 MCM and the annual growth rate was 0.6% (Table 3.27). This growth rate in the water balance was due to a higher recharge from the Indo-Gangetic Plains. The perennial rivers with flood waters during the monsoon also result in monsoonic water-logging and slow recharging of the ground water.

This sub-zone is very rich in the yield potential of aquifers as in almost all the districts the aquifers can yield water at a rate of more than 5 litre per second. In no district, saline water was encountered to any appreciable extent. But alkalinity was a major problem as not a single district was free from this water quality related problem. The alkali water occurred ranging from 20% in Allahabad to 95% in Farrukhabad. In majority of the districts more than 80% groundwater is alkaline.

AESR 4.4

River basins and water resource

No major river flows through this AESR. However, Bundelkhand part of the sub-region is watered by the southern tributaries of the Yamuna river like Chambal, Betwa, Sind, Kan, etc. Major irrigation projects in this sub-region are: Rajghat dam, Maudaha dam, Guntanala dam, Pathrai dam, Urmil dam and Lahchoora dam.

Irrigation

This AESR is mostly rainfed. Indeed, the sub-region is frequently experiencing droughts in summers and severe flooding during monsoons. In this sub-region, only 20% of the NSA is irrigated with an irrigation intensity as low as 109% (Table 3.21). A total of 0.7 M ha net area is irrigated with an equal contribution from both the states. Nearly half of the irrigated area gets irrigation from canal systems. Groundwater extraction from wells is an important source, mainly in MP part of this region. Tank irrigation system is insignificant in this sub-region. However, during recent years the area under tank irrigation has been increasing at an annual growth rate of about 6% in this sub-region.

Groundwater

The groundwater utilization is to the tune of 16% in MP part and 24% in UP part with a sub-regional mean of 20% (Table 3.27). The groundwater balance is around 3670 MCM/year in MP part while it is 2670 MCM/year in UP part. At the sub-regional level the groundwater has been declining at the rate of 1.9% per annum and the major contributor for this rate of decline was the UP portion where it was 3.3%. While the use of groundwater for irrigation has improved, its widespread use of groundwater has severely affected the sustainability of this resource. In a region that often suffers from weak monsoons and droughts, recharge of the groundwater is limited. Over extraction has already led to a fall in water table and if continued, would pose a serious threat to water security in the region.

This sub-region is moderately rich in the yield potential of aquifers. On an average in 40 to 50% area, the aquifers can yield water up to 5 litre per second and in 20 to 25% area it is more than 5 litre per second. In this sub-region alkaline water is a problem mostly in the UP part while saline water problem has been reported only in the Morena district of MP.

Demography

The AER 4 accounts for less than 11% of the India's landmass but is home to more than 17% of the national population. The demographic characteristics of the region are reflected by high population density, average level of literacy, and an adverse sex ratio (Table 3.31). The tribal population constitutes 3.2%. The workforce is overwhelmingly dominated by the primary sector, mainly crop raising and dairying. The

Table 3.31: Demographic profile of AER 4

Particulars	AESR 4.1	AESR 4.2	AESR 4.3	AESR 4.4	AER 4
Total population (million)	77.3	27.2	53.6	12.6	170.7
Rural population (% of total)	68	66	75	74	71
Population density (person/km^2)	584	289	723	234	479
Sex ratio (Females per '000 males)	865	936	894	858	884
Literacy (%)	64.6	66.4	62.4	61.5	63.8
Female literacy (%)	51.3	52.0	48.5	45.4	49.3
Disadvantaged population (%)*	21.3	23.1	22.7	25.8	22.4
Schedule castes, (%)	19.2	11.2	22.7	23.1	19.2
Schedule tribes, (%)	2.1	11.9	0.0	2.7	3.2
Total cultivators (million)	10.2	4.1	6.5	2.5	23.3
Total agricultural labourers (million)	4.0	1.7	3.6	1.1	10.4

Note: Reference year 2001; * Reference year 1991 average population density is 479 persons/sq km, which reflects the magnitude of strain on the limited land resources in this AER. The population density is particularly higher in the fertile plains of the Indo-Gangetic region. In AESR 4.3 a large number of districts have a density of more than 1000 persons/sq km. The density is comparatively low in the AESRs 4.2 and 4.4, which are confined to the traditional agricultural belts characterized by undulating topography, scarce irrigation facility and difficult climate. The sex ratio in AER 4 varies from 858 in AESR 4.4 to 936 in AESR 4.2. There could be two reasons for such an adverse sex ratio. Firstly, this society is typically male-dominated and therefore the preference for male child results into a wide spread female foeticide (Patel, 1984). Secondly, the increasing pressure of population on limited agricultural resource base and lack of alternative employment opportunities, compel the rural males to move to urban areas in search of jobs. Similarly, in this AER, there is a wide gap in the literacy rate among the male and female populations. The main reason for the lower female literacy is the lack of educational facilities in rural areas and the social restrictions on educating girl children.

The rate of population growth is very high in this region, well above the national average. Further, the decadal trend in population growth was quite discouraging as there was only a marginal decline in population growth during the 1990s, as compared to that during 1980s. During 1981 to 2001, the rate of growth in urban population was considerably higher in all the AESRs. This indicated rapid urbanization in this region. With this trend the share of urban population would be 36% in 2025.

The projected population in 2025 by AESRs is recorded in Table 3.32. These projections are based on the trend observed during 1981-2001. The projection at AESR or AER level was arrived at aggregating district projections made separately for rural and urban populations in each district. The underlying assumption for projecting population at district level was that the future decadal trend in population growth would follow the declining decadal growth rate as observed during 1981-2001 period. Applying the same logic at the country level population in India would be 1.35 billion by 2025, which is very close to United Nations projections for India (1.345 billion). According to this projection, population in AER 4 would reach 294.3 M in 2025, an increase of 72% over 2001 population. This will put tremendous pressure on land and water resources in this region.

Table 3.32: Population growth in AER 4

Particulars	AESR 4.1	AESR 4.2	AESR 4.3	AESR 4.4	AER 4
Average annual growth in population (%)					
	During 1981-1991				
Total population	2.85	2.34	2.53	2.65	2.65
Rural population	2.34	2.01	2.24	2.22	2.25
Urban population	4.31	3.10	3.65	4.12	3.87
	During 1991-2001				
Total population	2.84	2.25	2.43	2.42	2.58
Rural population	2.24	1.98	2.13	2.34	2.17
Urban population	4.35	2.82	3.48	2.65	3.70
Projected population by 2025 (million)	142.5	42.9	88.1	20.7	294.3
Urban population by 2025 (%)	42	36	29	21	36

Consumption, Nutrition and Poverty

The man needs a wide range of nutrients for a healthy and active life and these are derived from a wide range of food he takes. There are various indicators for nutritional intake but the single most important component is calorie consumption per capita. The underlying assumption is that, if people satisfy their daily calorie requirements from a reasonably varied diet, with all possibility, they would also satisfy their requirements for protein, minerals and vitamins. Further, rural and urban populations have different food habits and, therefore, their calorie intakes are also different. Though with greater access to information and fast development in market and infrastructure, the rural-urban gap in calorie intake is likely to reduce but it would persist for long time to come. Therefore, separate estimates for rural and urban sector were prepared (Table 3.33).

It is evident from Table 3.33 that there was considerable variation in both calorie intake as well as consumption of major food items across AESRs. In all the AESR, the daily average calorie intake was lower than the recommended daily allowances (RDA)[3] in both rural and urban areas. Consumption of cereals, edible oils and pulses was also lower than the RDA. Fish, egg, meat and other animal products were not a major source

[3] The daily recommended dietary allowances (recommended by Indian Council of Medical Research) for different food items for an average Indian are: Energy: 2200-2400 kcal; Cereal: 460 g.; Pulses: 40 g.; Edible oil: 20 g.; Sugar: 30 g.; Milk: 150 g.; Green leafy vegetables: 40 g., etc.

Table 3.33: Nutritional intake in AER 4 during 2000 and 2025 (projected)

Particulars	AESR 4.1	AESR 4.2	AESR 4.3	AESR 4.4	AER 4
Actual during 2000					
Calorie intake (kcal/day/capita)	2236	1971	2196	2242	2182
In rural areas	2269	2067	2216	2266	2221
In urban areas	2166	1782	2134	2175	2088
	Per capita daily consumption (g/day)				
Cereal	377	354	408	406	385
Pulses	27	23	32	29	28
Edible oil	16	24	16	16	17
Sugar	44	38	30	30	38
Milk	341	310	167	149	267
Green leafy vegetables	52	33	57	60	54
Calorie intake from cereals (%)	57	56	63	63	59
Calorie intake from animal products (%)	15	13	9	10	13
Estimates for 2025					
Calorie intake (kcal/day/capita)	2762	2422	2693	2742	2683
In rural areas	2723	2480	2659	2719	2665
In urban areas	2816	2317	2774	2827	2715
Per capita cereal consumption (g/day)	425	404	464	468	437
Calorie intake met from cereals (%)	52	53	58	59	55
Calorie intake met from animal products (%)	17	15	10	11	14

of protein in this region, as there is a sizable number of vegetarian population. However, these deficiencies were compensated by higher consumption of milk, sugar and green leafy vegetables. The current share of animal products (including milk) in the total calorie intake in this region was 13% which is expected to rise in all the AESR by 2025. Milk would continue to dominate as the major source of protein here. Changes in consumption pattern towards animal products will reduce the pressure on cereals production target to certain extent in all the AESRs.

It is to be noted here that in terms of nutrition and calorie intake this region was relatively better than other parts of the country, particularly if compared to the eastern, north-eastern and southern regions. This could be due to higher agricultural productivity and low poverty in this region, particularly in Punjab, Haryana and Gujarat parts though it is considerably high in UP and MP parts. However, over time, the per capita income has increased in all the AESRs though at a varied pace (Table 3.34).

Table 3.34: Income and poverty in AER 4

Particulars	AESR 4.1	AESR 4.2	AESR 4.3	AESR 4.4	AER 4
Population below poverty line (%)	17.0	14.8	31.6	34.3	22.5
Rural poverty	16.6	13.5	31.6	34.1	22.1
Urban poverty	18.0	18.2	31.4	34.7	23.5
Per capita NSDP* (Rs)					
In 1993-94	8479	7572	5152	5814	7093
In 2001-02	10507	9875	5852	6387	8641

Note: Reference year 1999-2000; * NSDP= Net State Domestic Product at 1993-94 prices.

Rural Infrastructure and Input Use in Agriculture

Agricultural development is highly dependent on the use of modern farm inputs and infrastructure development. Some infrastructural variables, particularly roads, markets and village electrification are expected to have direct impact on rural poverty (Roy and Pal, 2002). The status of rural infrastructure and use of modern farm inputs in this region, by AESRs, is presented in Table 3.35.

Table 3.35: Rural infrastructure and modern farm input use in AER 4

Particulars	AESR 4.1	AESR 4.2	AESR 4.3	AESR 4.4	AER 4
Rural infrastructure					
Village electrification (%)	92.1	96.5	80.3	88.5	88.8
Rural road (km/ '000 ha NSA)	13.6	11.2	13.1	13.5	13.0
Regulated market (No./'000 ha NSA)	0.70	0.37	0.38	0.39	0.53
Agricultural Co-operative Society (No./million population)	52.0	32.3	43.6	59.0	46.8
Post office (No./million population)	50.5	81.5	98.9	131.0	76.6
Modern farm input use (No./'000 ha NSA)					
Plough	151	191	636	152	261
Cart	94	62	120	76	90
Tractor	31	6	14	5	19
Sugarcane crusher	3	1	33	10	10
Pump set	147	68	117	29	107
Fertilizer consumption (kg/ha)	157	61	115	40	118
N: P: K application ratio	4:1.2:0.1	4:1.2:0.2	4:1.3:0.2	4:2.6:0.1	4:1.4:0.1

Note: Reference years are 1996 (road, market, co-operatives, post-office); 1997 (farm machinery); 1999 (electification) and 2000 (fertilizer consumption)

Perusal of the Table 3.35 reveals that the region has fairly developed infrastructure in terms of rural roads, markets, communications and village electrification. However, it varies considerably across AESRs. The AESR 4.1 is better than other sub-regions. In terms of farm mechanization AESR 4.3 is far ahead of other three AESRs. While in fertilizer consumption, AESRs 4.1 dominates because the AESRs 4.1 and 4.2 lie in the Indo-Gangetic Plains where the scope for farm mechanization and irrigation is better as compared to other two AESRs, particularly AESR 4.4.

Crop Diversification and Cost of Cultivation

This region has great potential for crop diversification toward oilseeds, pulses, fruits and agro-forestry through optimal use of rainfall, soil and water resources. These crops are not only economically better than rice and wheat but also involve low input requirements and less water consumption. Such a diversification strategy ensures both nutritional and environmental security in this region. The Union Budget 2003-04 has recognised diversification as one of the 'Panch Priorities' with swift adoption of sunrise technologies in addressing the problems of land degradation and waterlogging in this region. For this a provision of Rs. 50 crore was made for a Central Sector Scheme on hi-tech horticulture and precision farming.

The Johl Committee Report on diversification had also proposed to shift one million hectares of land from rice-wheat rotation to other crops in Punjab alone. For this the Report had proposed compensation to farmers for not growing rice and wheat and shifting to other crops under a "crop adjustment programme". This would not only reduce the cost of procurement, storage, and transportation, but also save the fast-degrading soil and the depleting water resources. However, the report has generated considerable debate in the government, particularly on the recommendation of "crop adjustment programme", which has put a question mark on its implementation in near future. Under such circumstances, contract farming may be one option towards diversification. The National Agriculture Policy envisaged that "private sector participation will be promoted through contract farming and land leasing arrangements to allow accelerated technology transfer, capital inflow and assured market for crop production, especially of oilseeds, cotton and horticultural crops". The Punjab Government has also argued that contract farming is one possible means of crop diversification where there is a real question of ecological survival and sustaining natural resources such as water and soil. However, much of the recent corporate interests in Punjab agriculture have been in basmati farming, which is one of the great water-guzzlers. Since contract farming is based on private corporate interests that are inherently profit-driven, there is no reason why these should coincide with the ecological requirements of a region.

Therefore, crop diversification can be more effectively encouraged through a system of relative pricing policy accompanied by a supportive system of public agricultural extension services. The unit costs of production of major crops across states in AER 4 are given in Table 3.36. As the district-wise cost of cultivation data are not available, the state level data published by the Ministry of Agriculture, Government of India, were used. It is evident from Table 3.36 that the unit cost of production of most of the crops varies considerably across states. Such variations arise from several sources. Some of them are influenced by the farmer's ability to use modern farm inputs while others are beyond their control, i.e., agro-ecological. If we compare the unit cost of production with minimum support price (MSP), paddy and wheat are more remunerative than pulses or oilseeds. The MSP therefore, has emerged as a major factor inhibiting crop diversification in this region particularly in Punjab, Haryana and Gangetic plains of UP. The policy of open-ended procurement of wheat and rice – that too from a handful of states in this region – favoured continuation of rice-wheat cropping sequence. Failure of technological breakthrough is also responsible for poor response towards pulses and oilseeds.

Table 3.36: Cost of production of major crops in different states in AER 4

(Cost C_2: Rs/qtl)

Crops	UP	MP	Punjab	Haryana	Gujarat	Rajasthan
Paddy	309	389	345	425	NA	NA
Wheat	363	475	412	392	402	393
Maize	523	571	NA	NA	499	499
Bajra	365	NA	NA	441	321	366
Gram	780	881	765	740	728	728
Arhar	880	824	NA	NA	856	NA
Rapeseed mustard	863	NA	1335	1381	985	985
Soyabean	NA	827	NA	NA	NA	904
Sugarcane	43	NA	NA	56	NA	NA
Cotton	NA	1708	1123	1083	1376	1000

Note: Reference year 1997/98; NA= not available

Watershed Development Activities

The Central Water Commission has identified 15 districts in this AER as drought-prone districts (Table 3.37). In order to improve water resources, watershed projects are being implemented in these regions under Drought Prone Area Programme (DPAP) and Integrated Watershed Development Programme (IWDP) schemes. In IWDP, the drought-prone and desert-prone areas are receiving particular attention. Five districts have also been covered under Desert Development Programme (DDP) mostly falling in AESR 4.2. In fact, this AESR is more prone to drought as all the districts in this sub-region experience droughts of moderate to extreme magnitudes at regular intervals.

Table 3.37: Districts covered under DPAP and DDP programmes

AESR	Name of the districts	
	DPAP	DDP
AESR 4.1	Bharatpur and Sawai Madhopur	Jaipur
AESR 4.2	Ahmedabad, Sabarkantha, Ajmer, Dungarpur, Tonk and Udaipur	Mehsana, Ajmer, Rajsamund and Udaipur
AESR 4.3	Bhind, Allahabad and Jalaun	—
AESR 4.4	Shivpuri, Banda, Jhansi and Lalitpur	—

Production Planning and Water Management

The constraints on development in this region are many and varied, including high climatic variability with low and erratic rainfall that leads to crop failure once in every 3-4 years; fragile soils prone to erosion and nutrient depletion; imperfect drainage leading to salinity and waterlogging; lowering of groundwater due to over-exploitation; poor infrastructure, and a very fast rate of population growth. At the aggregate level, this is a water deficit region. At the same time agriculture is the mainstay in this region. Therefore, more than 80% of the available water resources are diverted for irrigating crops. However, because of higher population growth and industrialization, the demand for water in non-agricultural sectors particularly in domestic and industrial sectors has been increasing at a faster rate. It is putting pressure on available water resources mostly on groundwater for irrigation. In many parts of this region, the associated problems with excess withdrawal of groundwater than recharge are alarming. Thus, efficient water management practices through production planning are essential. Some important issues at AESR level are discussed below:

AESR 4.1

- The major climatic production constraint is the erratic rainfall and the long dry spells during the monsoon. Efforts should be towards the *in situ* moisture conservation practices in the dry land areas of the sub-region. Appropriate technology should be developed for water harvesting and utilization of the harvested rainwater.

- Coarse-textured soil conditions result in low available soil moisture and increase the leaching of the nutrients. Hence, silt application from the ponds may be tried on a large scale to get over this production constraint.

- Both saline as well as sodic soil conditions are prevalent to a considerable extent in the sub-region. The salinity conditions are either due to underground saline aquifer or mismanagement in the canal command system. Techno-economically viable solutions are available for reclaiming these types of soils. These need be put into a large-scale adoption.

- Special fertilizer schedules need be adopted for the crops with particular reference to the application of zinc.

- Over-exploitation of groundwater resulting in the receding water table in some pockets of the sub-region needs be attended to and the irrigation techniques and crop selection done accordingly.

- Indiscriminate use of water in the canal command areas has resulted in waterlogging and salinity problems. The field drainage concept, which is lacking in the minds of farmers, planners and policy makers, need to be emphasised. The drainage technology developed for the reclamation of the waterlogged saline soils should be demonstrated on a large scale in the farmers' fields. But, as prevention is better than cure, appropriate water management technologies need popularization along with restriction on high water consuming crops in the canal command areas.

- There is an immediate need to propagate the conjunctive use technology not only for the use of poor quality water but also for restricting the development of waterlogging and secondary salinization.
- The climatic profile and crop water requirement of this sub-region indicate that rice-wheat system has a huge water deficit, as compared to that in other systems like maize-wheat or sorghum-wheat. It indicates that rice-wheat system is not sustainable in the long-run.

AESR 4.2

- Nutrient deficiency in soil is very common in this AESR. Therefore, proper nutrient management is important to realise the expected yields. Special fertilizer schedules need be adopted for the crops with particular reference to the application of nitrogen, phosphorus and zinc.
- This sub-region is highly prone to erratic rainfall, particularly seasonal drought during crop growth period.
- Salinity and sodicity, due to poor drainage, are at an alarming situation in the irrigated environments. The adoption of available solutions for reclaiming these types of soils needs to be encouraged.
- The quality of groundwater in this sub-region is very poor. Therefore instead of relying only on groundwater irrigation, conjunctive use of water should be encouraged for sustainable crop farming.
- The climatic profile and crop water requirement of this sub-region favour pulse cultivation where sorghum-pulse and maize-pulse systems are found to be quite sustainable in the long-run.

AESR 4.3

- Since tubewell is most common means of irrigating agriculture in this sub-region, the problem of groundwater mining is also very serious. A large number of blocks have already turned into black and many more are in the grey category. At the same time, compared to other sub-regions, this region receives better rainfall. Therefore, rainwater harvesting should be encouraged.

- The quality of groundwater in this sub-region is quite good. There are many such pockets with aquifers having yielding ability of more than 5 litres/sec. A systematic survey of such pockets and their utilization would be helpful in expanding irrigated agriculture.
- The areas with soil salinity need adoption of appropriate soil reclamation techniques and surface drainage for suitable crop husbandry.
- The climatic profile and crop water requirement of this sub-region highly favour cultivation of various pulse crops. Under rainfed conditions, sorghum and *Kharif* pulses are found to be most appropriate.

AESR 4.4

- This sub-region is characterized with huge groundwater potential. The quality is very good but the rate of its utilization is low (only 20%). Therefore, exploiting the vast groundwater would be helpful in expanding irrigated agriculture.
- Coarse-textured soil conditions with poor plant available water capacity (PAWC) result in low moisture availability. Hence silt application from the ponds may be tried to get over this production constraint.
- Irregular rainfall has often led to either drought or flood conditions. Therefore, rainwater harvesting through watershed development programme would be helpful.
- Increasing dependence on groundwater has resulted in a fall in water table. In recent years, water quality has also emerged as a major environmental concern.
- The climatic profile and crop water requirements of this sub-region indicate that sorghum followed by mustard or sorghum followed by rice/chick pea followed by wheat are most suitable cropping system.

Summing Up

The pressure on land and water resources is seriously threatening native plant and animal diversity in this region. With increasing agriculture and economic development the genetic pool is declining.

This decline, if unchecked and poorly managed can have unforeseen and adverse consequences for the sustainability of agriculture in the region.

- Soils in most parts of the AER 4 have moderate-to-high AWC indicating that crops like sugarcane, cotton, paddy, wheat etc can be grown safely. But the problem is with declining groundwater balance. Thus, in some pockets where the AWC values are below 150, dry land farming with water harvesting technique is appropriate.

- Empirical evidence shows that recharging of aquifers through watershed management has raised the groundwater table in the Aravalli foothills by 2 m within three years. Such management practices need to be adopted on a larger scale.

- Sub-surface drainage technology for waterlogged saline soils has resulted in formulation and execution of drainage schemes in Punjab, Haryana, Rajasthan and Gujarat. But more areas are still to be covered.

- Sub-surface drainage technology for reclamation of alkali soils in Rajasthan, Gujarat, Haryana, Punjab and Uttar Pradesh has resulted into an improvement in foodgrains production, employment generation and environment along with reduction in health hazards, increased groundwater recharge and increased fuel wood production (Datta et al 2003). But large-scale adoption of such technologies to saturate the problem areas is necessary, in which progress is very slow.

- Drought is one of the most costly water problems. It also has one of the highest probabilities of occurrence in arid and semi-arid regions. Unfortunately, drought management remains too often on a crisis management, focusing on relief measures rather than a risk management strategy.

- Despite massive investments in the canal water infrastructures in this region, many of these systems are getting decayed due to lack of maintenance. The performance of canal irrigation infrastructure is severely crippled.

- Since groundwater is a common property resource with individual benefits but collective costs, the issues of managing groundwater become vital. Promoting beneficiaries' participation in all aspects of water planning and management, with particular emphasis on Water User Associations can promote sustainable water use in the region.

- Crop diversification with cereals, pulses, oilseeds, vegetables, fruits, agro-forestry, etc. through optimal use of rainfall, soil and other natural resources will not only provide food security but also nutritional and environmental security. Crop diversification can be more effectively encouraged in this region through a system of relative pricing policy accompanied by a supportive system of public agricultural extension services. Contract farming with adequate safeguards can also be another means towards diversification.

IV. Resource Characterization for Sustaining Water-Food Security in AER 8

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Introduction

Agro-ecological situations are inevitably subjected to influence of physical environment. Agro-climatic factors like climate, soil, rainfall, etc. decide the cropping pattern and agricultural development and thereby the standard of living in any region. Based on agro-ecological characteristics, the country has been divided into 20 agro-ecological regions (NBSSLUP, 1996). Out of these, AER 8 covers Eastern Ghats, Tamil Nadu uplands and the Deccan Plateau (Karnataka). This zone has been further divided into three sub-regions namely AESR 8.1 (Seven districts of Tamil Nadu), AESR 8.2 (ten districts of Karnataka) and AESR 8.3 (thirteen districts of Tamil Nadu and Chitoor district of Andhra Pradesh). The details of the districts covered under different sub-regions are given in the Table 4.1.

Table 4.1: Districts covered under different AESRs

Regions	Composite districts	Present position
AESR 8.1	*Tamil Nadu:* Coimbatore, Kamarajar, Kanyakumari, Madurai, Tirunelveli, Chidambaranar, Dindigul Anna	*Tamil Nadu:* Coimbatore, Virudunagar, Kanyakumari, Madurai, Theni, Tirunelveli, Thoothukudi, Dindigul
AESR 8.2	*Karnataka:* Bangalore (rural), Chikmagalur, Chitradurga, Hassan, Kolar, Mandya, Mysore, Shimoga, Tumkur and Bangalore (urban)	*Karnataka:* Bangalore (rural), Chikmagalur, Chitradurga, Hassan, Kolar, Mandya, Mysore, Shimoga, Tumkur and Bangalore (urban)
AESR 8.3	*Tamil Nadu:* Chengalpattu, Dharmapuri, North Arcot, Pasumpon Muthuramalinga, Periyar, Pudukkottai, Ramanathapuram, Salem, South Arcot, Thanjavur, Tiruchirappalli	*Tamil Nadu:* Kancheepuram, Thiruvallur, Dharmapuri, Vellore, Sivagangai, Erode, Pudukkottai, Ramanathapuram, Salem, Namakkal, Thanjavur, Cuddalore, Nagappattinam, Thiruvarur, Tiruchirappalli Karur and Chitoor district of Andhra Pradesh

AESR 8.1 and AESR 8.3 cover most of the parts of Tamil Nadu state, while AESR 8.2 covers parts of Karnataka. Tamil Nadu state has a coastal line of 922 km and a land boundary of 1200 km. It lies between 8° 5' and 13 ° 35' at northern latitude and 76 ° 15' and 80 ° 20' of eastern longitude with an area of 1,30,069 sqkm.

The state of Tamil Nadu can be divided broadly into two natural divisions viz. (a) coastal plains and (b) hilly western areas. It can further be divided into coromandal plains comprising the districts of Chennai, South Arcot, North Arcot, Thiruvannamalai, and alluvial plains of Cauvery delta extending over Thanjavur, Nagapattinam and part of Trichy and dry southern plains in Madurai, Ramanathapuram, Sivagangai, Virudhunagar, Thoothukudi and Tirunelveli districts. It also extends a little into Western Ghats in Kanyakumari district. The Western Ghats averaging 914 to 2438 metre height runs along the western part of the AESR 8.1 with the hill groups of the Nilgiris and the Anamalais on either side of it. Palani hills, Varashanad and Andipatti ranges are the major offshoots of these Ghats. The other prominent hills comprise Javadis, Shervarayan, Kalrayans and Pachai Malais. These ranges continue on the south of river Cauvery. A plateau is found between these hills and the Western Ghats with an average elevation of 1000 feet raising westward. The highest peak of Doddapettah in the Nilgiris is 2636 metre above mean sea level (MSL).

The Western Ghats form a complete watershed and no river passes through them. The main streams viz. Paralyar, Vattassery Phazhayar etc are of limited length and fall into the Arabian Sea. All other rivers are the east-flowing rivers. The Eastern Ghats in the AESR 8.3 are not a complete watershed and as a result, the rivers pass through them at places, notable among them being the river Cauvery. The main rivers of these two AESR are Cauvery (with tributaries of Bhavani, Amaravathi, Noyyal), Vaigai, Tamaraparani, Palar, Ponniyar and Vellar.

Climate

Temperature

The climate of the three AESRs is basically tropical. Due to its proximity to the sea, the summer is less hot and winter is less cold. The temperature ranges between 22 and 33 °C in AESR 8.1 while it is 22 and 32 °C in AESR 8.3. The regions are exposed to both south-west and north-east monsoons. The mean temperature was worked out to be 28 °C for AESR 8.1 and 27 °C for AESR 8.3 (Table 4.2).

Table 4.2: Temperature in AER 8

(°C)

Regions	Maximum	Minimum	Mean
AESR 8.1	33	22	28
AESR 8.3	32	22	27

Evapotranspiration

The evapotranspiration of any region is an important factor, which determines the availability of water for irrigation. The actual evapotranspiration for AESR 8.1 and AESR 8.3 during the year 2000-2001 is given in the Table 4.3.

Table 4.3: Details of evapotranspiration in the study regions

(mm)

Regions	Winter	Summer	South West	North East	Annual
AESR 8.1	218	464	571	355	1607
AESR 8.3	201	512	629	344	1739

In both the regions, the evapotranspiration was found to be in the descending order from south-west monsoon, summer, north-east monsoon and winter periods. It was highest in during south-west monsoon period in both the regions.

Rainfall

The rainfall is the most important factor influencing the agricultural production in a region. The distribution of rainfall becomes critical in deciding the cropping pattern. The season-wise distribution of rainfall over decades for AER 8 is presented in Table 4.4. It is evidenced that the zones are benefited by both south-west and north-east monsoons. The mean annual rainfall in 2001 was worked out to be 699 mm, 876 mm and 798 mm for AESR 8.1, AESR 8.2 and AESR 8.3 respectively. The AESR 8.1 is being benefited by both south-west and north-east monsoons, accounting for 38% and 36% of the total rainfall, respectively. Compared to the north-east and south-west monsoons, the winter and summer monsoons behave erratically, as reflected by high coefficient of variation. The region has also receives summer showers to a moderate extent, which facilitate cultivation of rainfed crops The most of the rainfall of AESR 8.2, like that of region AESR 8.1, is received from the

Table 4.4: Pattern of rainfall in AESRs

(mm)

Region/Season	1980s		1990s		2000-01
	Mean	CV	Mean	CV	
AESR 8.1					
South west monsoon	135	45	172	33	267
North east monsoon	238	48	453	30	252
Winter	35	122	33	108	45
Summer	100	47	119	32	135
Annual	508	39	778	18	699
AESR 8.2					
South west monsoon			636	14	555
North east monsoon			231	35	170
Winter			7	88	2
Summer			129	24	150
Annual			1002	11	876
AESR 8.3					
South west monsoon	215	27	262	29	329
North east monsoon	218	26	393	32	348
Winter	25	130	18	147	7
Summer	71	30	77	47	114
Annual	528	21	750	23	798

two monsoons namely south-west and north-east monsoons. The region also receives moderate showers in summer. The mean rainfall and coefficient of variation season-wise worked out for the period 1995 to 2001, have shown that variation is high in winter season, and among the critical seasons the north-east monsoon is more erratic than the south-west monsoon.

The region though is benefited by both south-west and north-east monsoons, the later accounts for 43.7% of the total rainfall received while the former, for 41.2%. The region is also benefited by summer rains to a moderate extent. Of the critical monsoons, the coefficient of variation was found to be higher for north-east monsoon than the south-west monsoon.

Potential Evapotranspiration

The potential evapotranspirations for AESR 8.1, AESR 8.2 and AESR 8.3 are given in Table. 4.5.

Table 4.5: Potential evapotranspiration in AESRs

(mm)

Regions	Winter	Summer	South West	North East	Annual
AESR 8.1	324	594	874	333	2045
AESR 8.2	273	593	777	337	2025
AESR 8.3	318	593	777	337	2025

Relative Humidity

The relative humidity of a region decides the weather conditions and varies with the season. The humidity particulars of the sub-agroecological regions are provided in Table 4.6.

Table 4.6: Humidity in the study regions

(per cent)

Particulars	Winter	Summer	South West	North East	Annual average
	AESR 8.1				
08.30 hours	78	77	77	80	74
17.30 hours	52	43	67	67	57
	AESR 8.3				
08.30 hours	79	72	74	79	76
17.30 hours	53	46	56	66	55

The humidity was highest in the north-east monsoon followed by that in winter, south-west monsoon and summer at 8.30 hours in both the regions. But at 17.30 hours the humidity was the highest in south-west monsoon followed by that in north-east, winter and summer seasons in sub AER 1 region. In sub-AER 2 region, the humidity was high at the north-east monsoon followed by south-west monsoon, winter and summer periods.

Soils

The soils of the AESRs are highly heterogeneous having different parent materials of metamorphic, sedimentary, acid igneous rocks rich in soda lime feldspars, amphiboles and pyroxenes of gneissic rocks, chernochiltes and sand stones. Thus it is endowed with the collection of five major soil orders, viz. Alfisol, Entisol, Vertisol, Inceptisol and Ultisol.

Soil characteristics

The soil characteristics in AER 8 are given in Table 4.7. The productivity of the soil indicated that only 21.8% are in good productivity in AESR 8.1 and only 17.75% in AESR 8.3. Very deep soils account for 46.4% in AESR 8.1 and 48.85% in AESR 8.3. Also, the non-calcareous soils are predominant soil type in the region. The cation exchange capacity shows that most of the soils are with medium and low capacity. In general, the soils are neutral in reaction with some alkaline and acidic characteristics.

Table 4.7: Soil characteristics in AER 8

(lakh ha)

Soil characteristics	Classification of characters	AESR 8.1		AESR 8.3	
		Area	Percentage	Area	Percentage
Productivity	Extremely poor	3.76	19.71	3.74	6.28
	Poor	4.35	22.84	21.17	35.52
	Average	6.8	35.65	24.12	40.45
	Good	4.16	21.80	10.58	17.75
Depth	Shallow	1.47	7.69	1.43	2.39
	Moderately deep	4.13	21.63	15.92	26.70
	Deep	4.63	24.30	13.16	22.06
	Very deep	8.85	46.38	29.13	48.85
Texture	Loamy	4.11	21.56	9.59	16.09
	Coarse Loamy	2.06	10.78	10.81	18.13
	Fine Loamy	9.94	52.13	25.27	42.37
	Fine	2.96	15.53	13.96	23.41
Permeability	Slow	2.95	15.44	9.60	16.10
	Moderately slow	4.06	21.31	12.51	20.98
	Moderately rapid	6.29	32.99	24.99	41.90
	Rapid	5.77	30.27	12.54	21.03
Calcareousness	Calcareous	8.05	42.19	28.92	48.49
	Non-calcareous	11.03	57.81	30.72	51.51
CEC	Low	8.79	46.08	17.28	28.97
	Medium	7.69	40.31	29.60	49.63
	High	2.60	13.61	12.77	21.40
Soil Reaction	Medium acidic	1.02	5.34	7.41	12.43
	Slightly acid	0.27	1.43	4.12	6.91
	Neutral	8.94	46.86	21.54	36.11
	Mild Alkaline	4.53	23.73	11.65	19.54
	Moderately alkaline	3.27	17.16	10.53	17.65
	Strongly alkaline	1.04	5.47	4.39	7.36
Total		19.07	100.00	59.64	100.00

Soil fertility

The fertility status of the soil is decided based on its nitrogen, phosphorous and potassium content. The classification is done as low, medium and high fertile soils. But it depends on the nutrient quantity. The classification is given below:

Nitrogen (kg/ha)	: Low-<280	Medium 280 – 450	High >450
Phosphorous (kg/ha)	: Low -<11	Medium 11 –22	High >22
Potassium (kg/ha)	: Low-<140	Medium 140 – 280	High >280

It was found that nearly 80 and 89% of soils are in low nitrogen status in AESR 8.1 and AESR 8.3, respectively. In the case of phosphorous, medium status soil is more than 40% in both the regions. Potassium status is comparably good in both these regions (Table 4.8).

Table 4.8: Soil fertility status of AER 8

(per cent)

Major nutrients	Category	AER 8.1	AER 8.3
Nitrogen	Low	79.2	88.8
	Medium	15.8	8.4
	High	5.0	2.8
Phosphorus	Low	30.2	25.0
	Medium	49.5	43.2
	High	20.3	31.8
Potassium	Low	13.3	18.7
	Medium	45.8	37.6
	High	40.8	43.6

Land capability classification

The grouping of soils into different classes, sub-classes and units is done primarily on the basis of their ability to produce plants without deterioration for a long time. This classification is an interpretative classification based on the effect of the combination of climate and permanent soil characteristics on the risk of soil damages, limitations in use, productive capacity and the management requirement. The details of the land capability classification and their characteristics for AESR 8.1 are presented in Table 4.9 and for AESR 8.3 in Table 4.10.

All the soils within the land capability class are only similar in degree of limitations in soil-use. Land capability class indicates the degree of the total limitations on the land-use. The land capability class is further

Table 4.9: Land capability classification* for AESR 8.1

Land capability classification	Area (ha)	Limitations	Needs
Iie	165844	Erosion	Soil conservation and selection of crops
Iis	66801	Mild alkanity	Addition of organic manure
Iies	95513	Erosion, presences of kankar in the solum	Soil conservation and selection of crops
Iise	81676	Surface hardening and erosion	Chisel ploughing and erosion control
Iiw	5856	Soil wetness	Selection of crops
IIIe	47022	Erosion and run-off	Soil and water conservation
IIIes	488297	Erosion, medium soil depth, more of gravels	Soil and water conservation and selection of crops
IIIs	254874	Development of alkalinity and slow permeability	Drainage improvement and caution against alkalinity development
IIIse	227574	Heavy-texture, moderate alkalinity, sheet erosion, slow permeability	Soil conservation and selection of crops, drainage improvement
IIIw	4032	Excess water	Drainage improvement
IIIsw	78906	Alkalinity and calcareousness, wetness	Application of iron pyrites and drainage
Ives	124060	Erosion, coarse texture, shallow depth	Soil and water conservation, pasture development
Ivse	163684	Coarse-texture, low CEC, water holding capacity, low fertility and erosion	Addition of tank silt, organic manure and soil conservation and fertility management
Vse	6096	Sandy-texture, very low CEC, water holding capacity, excessive drainage, low fertility and severe erosion	Agro forestry

* Based on FAO standard classification

Table 4.10: Land capability classification* for AESR 8.3

Land capability classification	Area (ha)	Limitations	Needs
Iiw	17155	Soil wetness	Soil and water conservation
IIe	593790	Erosion, run off and topography	Soil conservation
Iis	770507	Moderate alkalinity, soil crust and poor fertility	Improving drainage and selection of crops
Iis	53060	Heavy texture, poor drainage and cracks	Improving drainage and selection of crops
Iis	9334	Rapid permeability, calcareous-ness, subsurface coarse textured	Application of organic matter
Iies	545054	Erosion, runoff, heavy texture and alkalinity development	Soil conservation, drainage and texture improvement
Iies	16767	Erosion , surface run off	Soil conservation
Iiws	118583	Soil moisture and alkalinity	Improving drainage soil reclamation
Iisw	39747	Soil and wetness associated limitations	Soil and water conservation
IIIe	356584	Erosion surface runoff	Soil conservation
IIIs	532397	Heavy texture and alkalinity	Drainage and texture improvement, conservation irrigation
IIIs	41050	Saline and alkaline	Soil reclamation
IIIes	1519808	Surface run-off, erosion, topography and shallow depth	Soil conservation, soil recla-mation and selection of crops
IIIes	10609	Alkalinity, run-off and erosion	Soil and water conservation, suitable crops and soil reclamation
IIIse	17375	Heavy texture, moderate alkalinity and sheet erosion	Soil conservation and drainage improvement
IIIse	66267	Shallow depth, calcareousness and erosion	Soil conservation and selection of crops and chisel ploughing
IIIsw	235686	Soil wetness associated limitations	Soil and water conservation
Ives	51228	Soil limitation (erosion, alkalinity and rapid permeability)	Soil conservation and reclamation and texture improvement
Ivs	9448	Surface coarse texture, severe crusting, low water holding capacity, CEC and fertility	Liberal addition of organic manure and fertility management
Ivse	2090	Shallow depth, coarse texture, low water holding capacity and CEC, severe erosion and low fertility	Selection of crops, liberal addition of organic manure and soil conservation
Vse	43281	Sandy texture, low water holding capacity, CEC, excessive drainage, severe erosion and very low fertility	Agro forestry

* Based on FAO standard classification

divided into sub-classes depending upon the kind of limitation for its use. There are three land capability sub-classes, viz. erosion (e), soil (s) and wetness (w).

Land Irrigability classification

The grouping of soils into different classes, sub-classes and units is done primarily on the basis of their suitability for irrigation without deterioration for a long time. This classification is an interpretative classification based on the effect of the combination of climate and permanent soil characteristics on the risk of soil damages, limitations in use, irrigability and the management requirement. All the soils within the land irrigability class are only similar in degree of limitations in use. Land irrigability class indicates the degree of the total limitations

Table 4.11: Land irrigability classification for AESR 8.1

Land capability classification	Area (ha)	Limitations
2s	144458	Presence of kankar nodules in the solum
2t	229291	Topography and run-off
2st	104714	Surface hardening, run off and topography
2d	46903	Moderate permeability and drainage, stratification of layers
2sd	2050	Fluvial action and waterlogging
3d	4075	Slow permeability and drainage
3s	226175	Slow permeability and alkalinity
3ts	913	Topography and coarse texture
3ts	20280	Topography, run-off and coarse texture
3ds	30461	Moderate drainage and presence of kankar in the solum
3ds	42914	Poor drainage and soil alkalinity
3sd	104715	Subsoil hardening and drainage
3st	544824	Erosion, shallow depth and topography
4ds	18913	Poor drainage, alkalinity, presence of gypsum
4st	287744	Coarse texture, low water holding capacity and topography
5st	6096	Sandy texture, low water holding capacity, CEC, excessive drainage and topography

on the land-use. The land irrigability class is further divided into sub-classes, depending upon the kind of limitation for its use. There are three land irrigability sub-classes, viz. topography (t), drainage (d), and soil problems (s).

The land irrigability classification for the study regions, viz. AESR 8.1 and AESR 8.3 are given in Table 4.11 and Table 4.12, respectively.

Table 4.12: Land irrigability classification for AESR 8.3

Land capability classification	Area (ha)	Limitations
2d	90760	Drainage problems
2d	16513	Moderate permeability
2t	389606	Run-off, topography
2st	297646	Erosion, topography, moderate run off
2s	546141	Moderate alkalinity low waterholding capacity
2s	5879	Moderate alkalinity
2sd	436930	Stratification, alkalinity impeded drainage
2ds	71920	Stratification alkalinity
2ts	544897	Topography, runoff and texture
3d	30930	Slow permeability, alkalinity and surface runoff
3s	870692	Shallow depth, low waterholding capacity, coarse fragments, kankar
3s	82492	Erosion, shallow depth, low waterholding capacity
3s	17375	Slow permeability, alkalinity and drainage
3t	112228	Topography, erosion
3st	798332	Shallow depth, low waterholding capacity, topography, erosion
3ts	150246	Topography, soil erosion and low waterholding capacity
3sd	535973	Poor drainage alkalinity and salinity
4d	1294	Drainage salinity, alkalinity
4sd	3793	Alkalinity, poor drainage
4s	24867	Soil limitations
4st	45371	Coarse texture, low waterholding capacity, cation exchange capacity, topography

Reclamation of degraded lands

Land degradation can be defined as a reduction in the soils capacity to produce in terms of quantity and quality goods and services. The lands get degraded on account of various reasons. Erosion by water, wind, chemical changes through accumulation of salts, waterlogging, reckless felling of trees, overgrazing in catchment areas of rivers, etc. are some of the major causes of land degradation. As good quality of land and soil is a pre-requisite for agricultural production, enough efforts must be made to map the degraded wastelands and steps to achieve reclamation of these wastelands. Keeping these in mind, the degraded wastelands in the study regions were identified and presented are in the Table 4.13

It was found that the total wastelands in AESR 8.1 was 6.9 lakh hectares which is 19.2% of the total geographical area of the region, while in AESR 8.3, it was 16.4 lakh hectares, 18.3% of the total geographical area of the region. Of the total area under wastelands, the area under upland with or without scrub is 40.4% and underutilized/degraded notified forest lands is 30.6% in AESR 8.1; and the corresponding figures being 36.1% and 36% in AESR 8.3.

Table 4.13: Area under wastelands in AESR 8.1 and 8.3

('000 ha)

Particulars	AESR 8.1	Per cent of total	AESR 8.3	Per cent of total
Gullied and ravenous lands	1	0.17	21	1.30
Upland with or without scrub	279	40.40	592	36.05
Water logged and marshy lands	0	0.01	45	2.73
Lands affected by salinity/ alkalinity	118	17.16	168	10.26
Shifting cultivation area	0	0.00	0	0.00
Underutilized / degraded notified forest lands	211	30.62	591	36.04
Degraded pastures / grazing land	0	0.03	17	1.06
Degraded lands under plantation crops	12	1.77	42	2.57
Sands – desertic / coastal	18	2.61	54	3.32
Mining / Industrial wastelands	4	0.53	13	0.77
Barren rocky / stony waste	25	3.58	86	5.23
Steep sloping area	22	3.11	11	0.67
Total	690	100	1639	100

The area under wastelands that can be considered for development across AESRs is nearly 4.28 lakh hectares in the AESR 8.1 and about 9.35 lakh hectares in AESR 8.3 (Table 4.14). These lands can be given more emphasis so that these could be brought for productive uses.

Table 4.14: Area under wastelands for development in AESR 8.1 and 8.3

(lakh ha)

Particulars	AESR 8.1	AESR 8.3
Gullied and / ravenous lands	1142 (0.3)	21305 (2.3)
Upland with or without scrub	278414 (65)	590394 (63.1)
Waterlogged and marshy lands	0 (0)	44675 (4.8)
Lands affected by salinity / alkalinity	118285 (27.6)	167583 (17.9)
Degraded pastures / grazing land	167 (0.1)	17364 (1.8)
Degraded lands under plantation crops	12179 (2.8)	40249 (4.3)
Sands – desertic / coastal	17888 (4.1)	53655 (5.7)
Total	428075 (100)	935226 (100)

Note: Figures within the parentheses indicate percentage to total

Agriculture

Land-use pattern

The pattern of land-use under AESR 8.1 and AESR 8.3 is presented in Table 4.15. Particulars of land utilization of the AESRs showed that the area under forest has been constant over the decades in both AESRs, accounting for 17% and 14% of the total geographical area, respectively in AESR 8.1 and AESR 8.3. It was interesting to note that the areas under current fallows and other fallow lands had increased over the decades in AESR 8.1, while reduced marginally in AESR 8.3. These fallow lands are marginal lands where agriculture is practised only when rainfall and other agro-climatic factors are favourable. The area under cultivable wasteland had marginally increased over the period.

Though there has been a rise in productivity and production of various crops in the state, one disappointing feature was that the net sown area and gross cropped area, which has marginally declined over the period. For instance, the net sown area had declined from 41.9 to 35.4% of the total geographical area in AESR 8.1, while it was 44.2 to 43.5% in AESR 8.3 from 1980s to 2001.

Table 4.15: Land-use pattern in AESR 8.1 and 8.3

(lakh ha)

Particulars	AESR 8.1			AESR 8.3		
	1980s	1990s	2001	1980s	1990s	2001
Forest	6.36 (17.73)	6.67 (17.65)	6.65 (17.65)	12.98 (14.30)	13.31 (14.90)	13.25 (14.80)
Barren & Unculturable Waste	1.35 (3.76)	1.50 (3.97)	1.28 (3.39)	4.15 (4.57)	3.60 (4.03)	3.45 (3.86)
Land put to non agricultural use	4.35 (12.14)	4.90 (12.98)	5.11 (13.56)	13.15 (14.50)	13.92 (15.59)	14.49 (16.19)
Culturable waste	0.80 (2.22)	1.16 (3.07)	1.23 (3.25)	2.17 (2.39)	2.05 (2.30)	2.27 (2.53)
Permanent Pastures & Grazing	0.31 (0.87)	0.24 (0.67)	0.25 (0.65)	1.07 (1.18)	0.93 (1.05)	0.94 (1.04)
Land under miscellaneous tree crops	0.41 (1.15)	0.64 (1.70)	0.71 (1.89)	1.39 (1.53)	1.64 (1.84)	1.81 (2.02)
Current fallows	4.57 (12.75)	3.91 (10.35)	4.55 (12.06)	11.46 (12.63)	6.50 (7.28)	6.74 (7.53)
Other fallow lands	2.65 (7.39)	3.97 (10.50)	4.60 (12.20)	4.33 (4.77)	6.80 (7.61)	7.63 (8.53)
Net Area sown	15.03 (41.90)	14.93 (39.52)	13.33 (35.36)	40.07 (44.16)	40.43 (45.28)	38.93 (43.50)
Area sown more than once	1.89	1.45	1.15	8.65	9.45	9.20
Total cropped area	16.92	16.38	14.47	48.83	49.65	48.14
Total geographical area	35.86	37.78	37.70	90.74	89.29	89.50

Note: Figures within the parentheses indicate percentage to total

The land use pattern (1999-2000) of AESR 8.2 (Table 4.16) indicated that nearly 16% of the geographical area was under forest. Forty-seven per cent of the area is the net sown area of this region.

Size of land holding

An agricultural census was made to study the size of land holding pattern in the regions. The number of operational holding was found to be constant over the decades in AESR 8.1 and it had declined significantly from 55.03 lakhs to 50.37 lakhs in AESR 8.3 (Table. 4.17). The decline in number of operational holdings in AESR 8.3 is mainly due to partition of different districts. A Similar picture was visualized in AESR 8.1 where there was a marginal decline in area under operational holdings. But in

Table 4.16: Land use pattern in AESR 8.2

(lakh ha)

Particulars	AESR 8.2
Geographical area	79.9 (100.00)
Forests	12.6 (15.77)
Land put to non-agriculture use	7.5 (9.39)
Barren unculturable land	3.8 (4.76)
Permanent pastures and grazing	7.6 (9.51)
Land under miscellaneous tree crops	1.5 (1.88)
Culturable waste	2.5 (3.13)
Fallow other than current fallow	2.2 (2.75)
Current fallow	4.6 (5.76)
Net area sown	37.7 (47.18)
Gross cropped area	43.2 (54.07)
Area sown more than once	5.5 (6.88)

Note: Figures within the parentheses indicate percentage to total geographical area.

AESR 8.3, there was a marginal increase in the size of landholdings. Frequent changes in the district boundaries, however, made it difficult to draw any inferences

Even though the proportion of large farmers was small, they were holding maximum land area. In AESR 8.3, the marginal, small, medium and large farmers were holding 15.7,13.2, 20.9, 2.3 lakh hectare land area, respectively.

Table 4.17: Number and area of operational landholdings in AER 8

Particulars	AESR 8.1		AESR 8.2		AESR 8.3	
	85-86	90-91	85-86	90-91	85-86	90-91
Number (lakhs)	20.57	20.93		29.20	55.03	50.37
Area (lakh ha)	22.15	21.34		45.02	54.93	52.54
Average size of holdings (ha)	1.08	1.02		1.50	1.00	1.04

Details about the size-groups of operational land holdings are given in Table 4.18. These are for the year 1995-96 in the case of AESR 8.1 and AESR 8.2, and for 1999 in the case of AESR 8.2. A perusal of this table indicated that marginal and small farmers constituted the major share of the farming population. On the contrary, their share in the area was less compared to other size groups. The major share of area, 11.68 lakh ha

Table 4.18: Details about size-groups of operational holdings in AER 8

Size-groups	Number	Area (lakh ha)	Average size of holding (ha)
		AESR 8. 1	
Marginal	15.1	5.30	0.4
Small	3.29	4.66	1.4
Medium	4.88	9.07	1.9
Large	0.12	2.32	18.9
Total	23.34	21.34	0.9
		AESR 8.2	
Marginal	15.16	7.14	0.5
Small	7.58	11.40	1.5
Semi Medium	4.32	11.68	2.7
Medium	10.84	10.56	5.7
Large	0.30	4.87	16.4
Total	29.20	45.02	1.5
		AESR 8.3	
Marginal	43.10	15.74	0.4
Small	9.38	13.18	1.4
Medium	5.92	20.92	3.5
Large	0.18	2.30	16.4
Total	58.58	52.84	0.9

was possessed by semi-medium farmers. The size of holding ranged from 0.5 to 16.4 ha, with the average size of 1.54 ha, which was nearer to the small farmers' size of holding.

It was also found the average size of holding of marginal, small and large farms were almost similar in all AESRs. But in the case of medium farms, the average size of holding was high in AESR 8.2 (5.7 ha) followed by AESR 8.3 (3.5 ha) and AESR 8.1 (1.9 ha).

Area and production of principal crops

The study on area under principal crops across AESRs in AER 8 revealed a declining trend over the decades (Table 4.19). For instance, in AESR 8.1, area under rice has declined from 3.29 lakh ha to 3.03 lakh ha from 1980s to 1990s and further to 2.53 lakh ha in 2001. This area registered a compound growth rate of - 2.75% per annum during 1980s and –2.26% during 1990s. Interestingly, in AESR 8.3, area under rice had registered a marginal increase from 18.41 lakh ha in 1980s to 18.45 lakh ha in 1990s, but declined to 18.25 lakh ha in 2001. A similar declining trend was visualized for other principal crops such as cholam, cumbu, ragi, groundnut and cotton.

Table 4.19: Area under principal crops in the study region

(lakh ha)

Crops	AESR 8.1			AESR 8.2		AESR 8.3		
	1980s	1990s	2001	1990s	2001	1980s	1990s	2001
Rice	3.29 (-2.75)	3.03 (-2.26)	2.53	5.55	6.66	18.41 (2.50)	18.45 (1.60)	18.25
Cholam	2.65 (-1.16)	1.86 (1.64)	1.57	2.34	1.29	4.08 (-0.85)	2.49 (-7.29)	1.74
Cumbu	0.67 (-3.82)	0.38 (0.49)	0.32	0.18	0.09	2.37 (-2.14)	1.58 (-7.59)	0.94
Ragi	0.13 (11.47)	0.03 (7.84)	0.02	10.10	5.29	1.73 (1.4)	1.32 (-4.50)	1.25
Sugarcane	0.32 (-2.49)	0.39 (2.72)	0.43	0.78	1.03	1.64 (3.93)	2.37 (3.87)	2.73
Cotton	1.28 (1.96)	0.93 (-7.6)	0.47			1.01 (4.26)	1.46 (0.78)	1.23
Groundnut	1.28 (2.59)	1.14 (5.29)	0.64	5.44	5.06	7.83 (2.29)	8.67 (-3.56)	6.35
Banana	0.23 (-3.21)	0.33 (4.81)	0.39			0.33 (2.72)	0.45 (2.81)	0.44
Mango	0.15 (2.54)	0.25 (7.55)	0.34			0.26 (5.11)	0.53 (8.25)	0.74

Note: Figures in parentheses indicate worked out compound growth rate.

Contrary to this, the area under crops like sugarcane, coconut, banana and mango had registered a positive growth rate. For example, the area under mango in AESR 8.1 had increased from 0.15 lakh ha (1980s) to 0.25 lakh ha (1990s) and further to 0.34 lakh ha during 2000-2001. A similar trend was seen in AESR 8.3 also. In the case of pulses, the area had been increasing in AESR 8.3. In case of Gingelly the area had increased from 0.20 lakh ha during 1980s to 0.23 lakh ha during 1990s, but declined to 0.156 lakh ha during 2000-2001 in AESR 8.1. The same trend was noticed in AESR 8.3.

It was found that cereals occupied a major area of cultivation in AESR 8.2. Among the cereals, rice, ragi and maize were the major crops. Though the total area under cereals had declined from 18.89 lakh ha in 1990-91 to 14.94 ha in 1999-2000, the area under rice has increased from 5.55 lakh ha during 1990-91 to 6.66 lakh ha. in 1999-2000.

The production of principal crops lucidly indicated that the crops such as rice, sugarcane, banana and mango had registered increase in production over the decades (Table 4.20). It was interesting to note that though the area under rice had registered a negative compound growth rate, increase in productivity helped to attain a higher level of production in both the AESRs. Crops like cholam, cumbu, ragi and cotton had registered a negative compound growth rate of production. The decline in production of these coarse cereals was mainly attributed to reduction in the area under these crops. Production of crops like sugarcane, banana and mango had a significant positive compound growth rate, mainly due to increase in their areas.

Table 4.20: Production of principal crops in ASERs

(lakh tonnes)

Crops	AESR 8.1			AESR 8.2		AESR 8.3		
	1980s	1990s	2000-01	1990s	2000-01	1980s	1990s	2000-01
Rice	9.64 (4.09)	12.02 (-0.14)	11.79	13.00	18.18	44.20 (5.17)	55.09 (2.37)	61.79
Cholam	2.41 (2.37)	1.82 (-3.62)	1.51	0.05	0.05	3.43 (6.70)	2.53 (-6.96)	1.55
Cumbu	0.73 (0.56)	0.60 (2.91)	0.54	1.81	1.17	2.25 (1.90)	1.74 (-5.56)	1.16
Ragi	0.24 (-8.35)	0.08 (-8.58)	0.06	9.49	7.25	2.64 (2.67)	2.57 (-4.25)	2.54
Sugarcane	33.85 (-1.85)	43.58 (5.04)	55.50	83.50	112.83	162.88 (4.52)	249.63 (4.41)	311.36
Cotton	2.06 (4.40)	1.51 (-8.13)	0.98			1.67 (11.69)	2.40 (1.08)	2.19
Groundnut	1.55 (2.99)	1.82 (0.93)	1.26	7.95	3.23	8.73 (5.45)	13.52 (-0.70)	12.33
Banana	5.69 (5.13)	12.89 (10.46)	15.45			8.46 (8.54)	17.61 (4.57)	15.18
Mango	1.17 (-13.41)	1.06 (11.44)	1.99			1.93 (-5.28)	3.36 (1.16)	3.57

Resilience of crop production

In general, the area under foodgrains particularly rice has been found declining over the decades. It may be appropriate to indicate that even though the agriculture sector has achieved a breakthrough in the production of paddy, acute shortages are being felt with regard to production of pulses, cotton and oilseeds. The textile mills in both the AESRs require 45 lakh bales of cotton whereas the production is less than four lakh bales per annum, leaving a huge demand – supply gap. However, a comparison of the productivity levels of the principal crops in these regions revealed that they were able to achieve the highest yield in respect of paddy, relegating Punjab to the second position. In respect of sugarcane, groundnut and cotton also, these regions were on first position. But there is urgent need for breakthrough in case of productivity of pulses and oilseeds like gingelly and sunflower.

Irrigated area

Considering the irrigation sector of the different agro-ecological regions, during 1980s, the total net irrigated area in AESR 8.1 was about 5.73 lakh hectares, which had increased slightly to 6.42 lakh hectares during 1990s and further to 6.49 lakh hectares at the year ending 2000-2001 (Table 4.21).

In AESR 8.2, the net area irrigated was found has been declining over the decade. It was also seen that though the share of area irrigated by wells had been increasing over the years, the net irrigated area by all the sources had declined from 7.88 lakh ha in 1990-91 to 7.57 lakh ha in 2000-01. It was because that the agro-ecological sub-region was receiving near normal rainfall in the past decade. In some years, there was even more than normal rainfall in that region.

The net area irrigated in AESR 8.3 had increased from 19.55 lakh hectares in 1980s to 22.37 lakh hectares in 2001. This increase in the net area irrigated across agro-ecological regions was mainly due to various major and minor irrigation projects. Though one could also probe the apparent marginal fluctuations after the 1980s, what is more lucid is the changing composition of the sources of irrigation. Among the different sources, surface flows represented by tanks and canals have been constantly and continuously declining over the decades. The declining trend is more pronounced in relative terms. For instance, area irrigated by tanks has decreased significantly from 25.58% to 20.38% of the net area irrigated over the period in AESR 8.1. A similar trend is visualized in AESR 8.3 also. On the other hand, the area irrigated by groundwater through wells had been increasing significantly both in absolute and relative terms. Wells became a dominant source of irrigation.

Table 4.21: Source-wise net area irrigated in AER 8

(lakh ha)

Particulars	1980s		1990s		2001	
	Area	%	Area	%	Area	%
			AESR 8.1			
Canals	1.32	23.04	1.41	22.04	1.29	19.83
Tanks	1.47	25.58	1.54	24.05	1.32	20.38
Tube wells	0.02	0.38	0.07	1.14	0.10	1.58
Ordinary wells	2.90	50.64	3.36	52.36	3.74	57.59
Others	0.02	0.36	0.03	0.41	0.04	0.62
Total	5.73	100.00	6.42	100.00	6.49	100.00
			AESR 8.2			
Canals			3.21	40.8	2.78	36.8
Tanks			1.70	21.6	1.54	20.4
Tube wells			0.94	12.0	2.36	31.2
Ordinary wells			1.73	21.9	0.66	8.7
Others			0.29	3.7	0.22	2.9
Total			7.88	100.0	7.57	100.0
			AESR 8.3			
Canals	6.53	33.38	6.82	32.02	7.04	31.48
Tanks	4.68	23.93	4.64	21.78	4.56	20.39
Tube wells	1.23	6.30	1.88	8.82	2.18	9.73
Ordinary wells	6.94	35.52	7.82	36.73	8.47	37.86
Others	0.17	0.87	0.14	0.65	0.12	0.54
Total	19.55	100.00	21.30	100.00	22.37	100.00

Fertilizer consumption

The trend in fertilizer consumption across agro-ecological regions indicated that the consumption of various nitrogenous, phosphatic and potassic fertilizers had increased marginally over the decades. The increase was prominent in potassic fertilizers in both the agro-ecological regions (Table 4.22). The average consumption of NPK in AESR 8.2 was 87 kg/ha. The fertilizer consumption rate has been appreciable at 4 % in this region compared to the state level consumption of less than 1%.

Table 4.22: Trend in fertilizer consumption in AESR 8.1 and 8.3

(kg/ha)

Fertiliser consumption	AESR 8.1			AESR 8.3		
	1980s	1990s	2000-01	1980s	1990s	2000-01
Nitrogen	65.01	67.16	89.84	59.39	66.47	85.17
Phosphorous	23.64	25.64	34.55	22.53	24.17	31.16
Potassium	29.55	48.84	41.47	24.58	30.21	29.08

Animal husbandry

The study on livestock population across agro-ecological regions indicate that the total livestock population had declined marginally over the years. It was evidenced that in AESR 8.1, it had reduced from 54.04 lakh to 53.47 lakh during the period 1982-1997. The same trend was seen in AESR 8.3. It was interesting to note that though the total livestock population had declined, the number of cattle heads had increased marginally in both the agro-ecological sub-regions. The poultry population had increased significantly over the years in the entire AESRs.

Table 4.23: Livestock population in AER 8

(lakhs)

Particulars	AESR 8.1		AESR 8.2		AESR 8.3	
	1982	1997	1983	1990	1982	1997
Cattle	19.42	16.74	59.37	51.31	83.40	76.07
Buffaloes	7.37	5.30	16.12	17.88	24.34	21.52
Sheep	12.86	13.85	28.05	26.60	42.33	39.77
Goats	10.47	12.75	21.40	17.08	41.74	50.23
Pigs	1.52	1.33			5.38	4.87
Others	0.42	3.51			0.47	11.86
Total	54.04	53.47	124.95	112.87	205.90	204.32
Poultry	39.73	67.66	70.78	72.87	142.63	204.21

The production of various livestock products indicated that the milk production had increased dramatically over the period of years in both the AESRs. This might be due to introduction of more crossbreds in the livestock sector. Similarly, the egg production had also increased from 10.49 lakh during 1980s to 15.05 lakh during 2000-2001 in AESR 8.3. A similar trend was seen in AESR 8.1 also where the total egg production had increased from 2.35 to 2.85 lakh tonnes during this period.

Table 4.24: Production of animal husbandry sector in AESR 8.1 and 8.3

(lakh tonnes)

Particulars	80's	90's	2001
		AESR 8.1	
Milk production	6.98	9.18	13.22
Egg production ('000 lakhs)	2.35	4.09	2.85
Marine fish production	1.02	0.80	0.88
Inland fish production	0.14	0.25	0.28
		AESR 8.3	
Milk production	19.74	28.04	35.23
Egg production ('000 lakhs)	10.49	23.78	15.05
Marine fish production	1.59	2.53	2.75
Inland fish production	0.61	0.78	0.83

Introduction of various inland fisheries development programmes by the state had helped to increase the inland fish production. For instance, the inland fish production had increased from 0.14 to 0.28 lakh tonnes in AESR 8.1 and from 0.61 to 0.83 lakh tonnes in AESR 8.3 during the period 1980-2000.

Animal husbandry programme and veterinary facilities

The AESR 8.1 and AESR 8.3 have good veterinary facilities like artificial insemination availability of health care services through veterinary hospitals and camps etc. For the supply of cattle feed, Government runs feed manufacturing units in these regions. During 2000, a Special Scheme for Animal Health Care was launched, especially to take care of rural livestock. The objective of this Scheme was to ensure proper medical facilities at the door-steps of the livestock rearers, free of cost through camp approach in each block every month. The measures taken by the Animal Husbandry Department in strengthening veterinary infrastructure such as Polyclinics, Veterinary Hospitals, Veterinary Dispensaries and Sub-Centres have been very effective in arresting and controlling diseases such as rinderpest, foot and mouth, black quarter, anthrax and ranikhet.

It was found that well structured milk collection and marketing facilities are available in these regions. To prevent exploitation by middlemen, Milk Producers' Cooperatives have been established. However, entry of numerous dairy farms functioning in these regions has opened up an opportunity of better marketing by the farmers while throwing a challenge to Government's procurement / pricing policy.

AESR 8.1 and AESR 8.3, having a total coastal length of 1000 km and a continental shelf of 41412 sqkm, have rich potential of fish resources. They have high export potential accounting for 15% of the total fish landing in India. The Government has initiated development of Fishing Harbours and landing facilities all along the coastal lines. In AESR 8.2, the fish production had increased from 31991 tonnes in 1988-89 to 83582 tonnes in 1999-2000, and increase of 260%.

Water Resources and Irrigation

River systems

There are about 33 river basins, which are grouped into 17 river basins (Table 4.25). It is evident from the table that some of the river basins lie in two AESRs. Among the river basins Palar, Varahanadhi, Paravanar, velar in AESR 8.3 and Vaippar and Kodaiyar basins in AESR 8.1 are surplus in water sources.

Table 4.25: River Basins in AER 8

AESR 8.1	AESR 8.2	AESR 8.3
Gundar	Cauvery	Agniyar
Kallar	North Pennar	Chennai
Kodaiyar	South Pennar	Part of Gundar
Nambiyar	Palar	Palar
Pambar and Kottakaraiyar	Krishna	Pambar and Kottakaraiyar
Parambikulam Aliyar		Parambikulam Aliyar
Project		Project
Tambaraparani		Paravanar
Vaigai		Ponnaiyar
Vaippar		Part of Vaigai
		Part of Vaippar
		Varahanadhi
		Vellar
		Cauvery

Performance of irrigation systems

The major irrigation systems in the regions are canal, tank and well irrigation systems. Irrigation water requirement for second season is mostly met through groundwater resources and partly through rainfed tanks. The irrigation efficiency varies among the irrigation systems. In general an overall efficiency of 40% for tanks and canals and 75% for wells is usually followed for estimating water demand.

The total water-use at farm level was calculated using the effective rainfall and the irrigation water applied which was calculated using the V notch readings covering different AESRs. (Canal system - AESR 8.1, Tank system - AESR 8.1and AESR 8.3, and Well irrigation - AESR 8.3) The total water was considered in working out the productivity per unit of water, because it takes in account effective rainfall, which otherwise will be biased. The productivity per unit of water for the 4 crops considered in the study was worked out by dividing the total water used by the crop yield and the results are presented in Tables 4.26 to 4.29

AESR 8.1 (Canal system)

A Comparison of the different systems in Lower Bhavani Project, Arachalur (middle region) revealed maximum yield and profit per unit quantity of water. However, the second season (Sept - Dec), recorded less grain yield compared to the previous season, due to rat problem and occurrence of heavy rain during the anthesis. Muthur (tail end area) recorded low yield and low productivity per unit quantity of water due to late release and early closing of water. The early closing of water coincided with peak water requirement of the crop. Profit per unit of water was higher and the quantity of water used was comparatively less. Considering the total quantity of irrigation water applied, Tambraparani system recorded higher followed by Periyar Vaigai and Lower Bhavani systems. Effective turn system reduced the total quantity of water utilised by farmers in Lower Bhavani system and resulted in maximum gross return.

A comparison of the different canal systems revealed that, in Tambraparani system the farmers used 59.5% more water for paddy than in the experimental situations, and it was followed by Periyar, Vaigai (32.9%) and LBP (30.7%) systems.

AESR 8.1 and AESR 8.3 (Tank system)

In tank irrigation systems, the system tanks recorded maximum yield and productivity per unit of water than the non- system tanks. Later, depend fully on rainfall run-off, and have comparatively lesser storage, resulting in low productivity per unit of water. In general, productivity

Table 4.26: Productivity of water under canal system in AESR 8.1

Particulars	Lower Bhavani		Periyar-Vaigai	Tambra-parani
	Arachalur	Muthur	Kodikulam	Vallanad
Crop	Paddy	Paddy	Paddy	Paddy
Soil type	Red non-calcareous	Red non-calcareous	Red soil	Alluvial soil
Season	Aug-Dec	Aug-Dec	Oct-Feb	Nov-Mar
Varieties	IR 20*, Bhavani	IR 20*, ADT 39	IR 20*, ADT 39	IR 20*, ADT 39
Cost of cultivation (Rs/ha)	12356	14237	14140	13450
Grain yield (kg/ha)	5254	5080	4920	4694
Straw yield (t/ha)	6.6	6.4	6.1	5.8
Gross return (Rs/ha)	21016	24384	23616	22531
Net return (Rs/ha)	8660	10147	9476	9081
Effective rainfall (cm)	41.9	34.9	32.2	29.9
Irrigation water applied (cm)	69.1	74.1	142.3	148.4
Total water consumed (cm)	111.00	109.0	174.5	178.3
Productivity (kg/ha.cm)	47.3	46.6	28.2	26.3
Profitability (Rs/ha.cm)	109.0	93.1	54.3	50.9
Water requirement (lit/kg)	2113	2146	3547	3799

* Considered for this analysis.

under the tank systems is relatively lower than under the canal systems. The farmers used 10.3% more water compared to that in the experimental levels.

AESR 8.3 (Well irrigation)

Well irrigation has recorded the maximum output per unit quantity of water due to effective utilization of water. Higher productivity and profit per unit of water was observed in Periyar district than Salem. Even though, for the same variety and input use conditions, in both the districts, the rice was lower in Salem district, compared to that in Periyar district and it was mainly attributed to the pest and diseases in the crop season. However, compared to other systems, the total quantity of water consumed by crop was low due to limited but controlled water supply by the farmers. Compared to rice, sugarcane crop had recorded maximum productivity and profit per unit of water. Being an annual crop, it was due to high production and remunerative price fixed by sugarcane industry than for other crops.

Table 4.27: Productivity of water under tank system in AESR 8.1 and 8.3

Particulars	AESR 8.1		AESR 8.3	
	System	Non-System	System	Non-System
Crop	Paddy	Paddy	Paddy	Paddy
Soil type	Red soil	Red soil	Red soil	Red soil
Season	Sep-Jan	Oct-Feb	Oct-Feb	Oct-Feb
Varieties	IR 20*, ADT36	IR 20*, ADT 36	IR 20*, ADT 36	IR 20*, ADT 36,
Cost of cultivation (Rs/ha)	11630	10225	10615	10223
Grain yield (kg/ha)	3740	3240	3420	3025
Straw yield (t/ha)	4.9	4.3	4.7	4.5
Gross return (Rs/ha)	17952	15552	16416	14520
Net return (Rs/ha)	6322	5327	5801	4297
Effective rainfall (cm)	35.2	35.2	37	37
Irrigation water applied (cm)	63.3	48.3	65.2	47.6
Well water applied (cm)	46.5	51.5	44.2	49.5
Total water consumed(cm)	145	135	146.4	134.1
Productivity (kg/ha.cm)	25.8	24.0	23.4	22.6
Profitability (Rs/ha.cm)	43.6	39.4	39.6	32.0
Water requirement (lit/kg)	3877	4167	4281	4433

* Considered for this analysis.

A comparison of water use by the farmers and experimental situations revealed that, the farmers used 3.6% more water for paddy, 66.7% for sugarcane, 103.5% for groundnut, and 83.4% for cotton.

It could be concluded that rice yielded comparatively low returns per unit quantity of water both in terms of product and profit. Compared to rice, the sugarcane crop followed by groundnut recorded maximum productivity and profit per unit of water.

Groundwater

The importance and need of water, particularly for the agriculture and its role in augmenting food production needs no emphasis since water is the basic input. Prudential planning for systematic and scientific development of groundwater resources by means of various types of groundwater abstraction structures requires balanced estimation of its potential. The groundwater potential, net draft, balance potential available and stages of groundwater development are furnished in Table 4.29.

Table 4.28: Productivity of water under well irrigation in AESR 8.3

Particulars	Periyar	Salem	Periyar	Salem	Periyar	Salem	Periyar	Salem
Crop	Paddy	Paddy	Sugarcane	Sugarcane	Cotton	Cotton	Groundnut	Groundnut
Soil type	Red soil	Red soil	Red soil	Red soil	Red soil	Red soil	Red soil	Red soil
Season	Aug-Dec	Aug-Dec	Jun-May	Jun-May	Aug-Jan	Aug-Jan	Jul-Oct	Jul-Oct
Varieties	IR 20* Bhavani	IR 20* Bhavani	COC671* COC771	COC671* COC419	MCU5* MCU9	LRA5166* SUVIN	TMV1* TMV2	VRI1* TMV1
Cost of cultivation (Rs/ha)	11340	11250	41370	39580	8970	8320	7820	6520
Yield (kg/ha)	4820	3930	157550	143240	1225	932	3825	2845
Gross return (Rs/ha)	19280	15720	86652	78782	19600	14912	16448	12233
Net return (Rs/ha)	7940	4470	45282	39202	10630	6592	8628	5713
Effective rainfall (cm)	38.2	32.3	68	65	39.2	35	36	34
Irrigation water applied (cm)	70	65	188	174	50	42	33	30
Total water consumed (cm)	108.2	97.3	256	239	89.2	77	69	64
Productivity (kg/ha.cm)	44.5	40.4	615.4	599.3	13.7	12.1	55.43	44.45
Profitability (Rs/ha.cm)	73	45.9	176.9	164	119	85.6	125	89
Water requirement (lit/kg)	2245	2476	162	167	7282	8262	1804	2250

* Considered for this analysis.

Table 4.29: Groundwater perspectives of AESR 8.1 and AESR 8.3

(MCM)

Particulars		AESR 8.1	AESR 8.3
Annual groundwater recharge		6309	21149
Net groundwater recharge		5678	19034
Allocation for industries and domestic uses		215	637
Net groundwater recharge available for irrigation		5464	18397
Gross groundwater draft		3172	13126
Balance groundwater available		2291	5270
Stage of GW development (%)	January 1998	65	56
	5 years after	68	59
Probable number of wells feasible		124110	302163

It was found that the stage of groundwater development was at about 65% in AESR 8.1 and 56% in AESR 8.3, implying the scope for its further development in these two agro-ecological regions.

The groundwater potential of the sub-region AESR 8.2 is 6001.63 MCM. The status of groundwater use for irrigation stands at 27% of the available potential leaving large scope for future development. Inspite of increase in utilization of groundwater the balance has not depleted but has marginally improved which can be ascribed to large scale rainwater conservation method practised through soil conservation measures in the region.

It was inferred that the groundwater development in this agro ecological region was at 36.3% (Table 4.30). Though it indicated possibility for further development, groundwater was not being exploited uniformly

Table 4.30: Groundwater perspectives of AESR 8.2

(MCM)

Particulars	AESR 8.2
Annual natural recharge	7396
Provision for drinking and industrial use	1100
Available recharge	6296
Utilisable recharge	5649
Net draft	2104.5
Balance groundwater available	4191.5
Utilisable irrigation potential for development (ha)	1136480
Stage of development in %	36.3

throughout the region. Some districts in this agro-ecological region, namely Bangalore, Chitradurga, Kolar, Mysore and Tumkur had over-exploited blocks. The classification of grey, dark and over-exploited blocks in these districts is given in Table 4.31.

Bangalore district is having blocks in all three categories, viz. grey, dark and over exploitation. Totally eight blocks are grey blocks and six blocks are in dark and over-exploited categories of groundwater exploitation. Where adequate surface water was available, utilization of groundwater resources was found minimum.

Table 4.31: Grey, dark and over- exploited blocks in AESR 8.2

District	Grey Blocks	Dark Blocks	Over Exploited Blocks
Bangalore	Ramanagaram Doddaballapur	Bangalore(S) Chennapatna	Anekal Bangalore (N) Devana halli Hoskote
Chitradurga	Molakalmur	-	-
Kolar	Chikballapura Gauribidanur Sidlaghatta	Mulbagal	Kolar Malur
Mysore	-	Kollegal	-
Tumkur	Gubbi Madhugiri	Tiptur Tumkur	-
Total	8 Blocks	6 Blocks	6 Blocks

Note: Status as on March 1998.

Water Resources: Utilization and Management

Water in general, is used for irrigation, industrial sector, domestic sector and livestock sector. Among these sectors, agriculture is the major consumer. Irrigation water requirement as net water requirement is presented in Table 4.32. The net water requirement for agriculture in AESR 8.1 was calculated as 6781 MCM whereas it was 13609 MCM in AESR 8.3 for the year 1999-2000. This water requirement was estimated at crop level (did not include irrigation efficiency of the irrigation systems). The irrigation potential and actual areas irrigated were found to differ in all the sources of irrigation and are presented in Table 4.33 for both AESRs.

Table 4.32: Irrigation water requirements of AESR 8.1 and 8.3

(MCM)

AESR 8.1	Total net crop-water requirement	AESR 8. 3	Total net crop-water requirement
Coimbatore	834	Chennai	51
Dindigul	681	Kancheepuram	1713
Madurai	1958	Viluppuram	776
Virudunagar	947	Vellore	625
Thirunelveli	1530	Thiruvannamalai	590
Thoothukudi	419	Cuddalore	1399
Kaniyakumari	412	Salem	375
		Dharmapuri	846
		Erode	187
		Tiruchirappalli	2225
		Thanjavur	2074
		Pudukkottai	854
		Ramanathapuram	1004
		Sivagangai	891
Total	6781	Total	13609

Table 4.33: Potential and actual area irrigated by different sources

(M ha)

Net area irrigated by	Sources	Potential	Potential tapped	Actual irrigated area
Surface flows		2.50	2.40	1.52
	Canals			0.80
	Tanks			0.70
	Others			0.02
Groundwater	Wells	3.20	1.60	1.40
Total	5.70	4.00	2.92	
Area irrigated more than once				0.70
Gross area irrigated				3.60

Demography

The demographic particulars of any region are important because the human labour force is crucial in production of various goods and providing services. The population particulars of the study regions are presented in Table 4.34. According to 2001 census; the total population is 175.88 lakh in AESR 8.1, 266.54 lakh in AESR 8.2, and 395.41 lakh in AESR 8.3. The literacy percentage was worked out to be 69.04%, 62.0% and 60.67% during 2001 in AESR 8.1, AESR 8.2 and AESR 8.3, respectively.

Table 4.34: Population particulars of AER 8

Particulars		1981	1991	2001
		AESR 8.1		
Population (lakhs)	Male	70.01	79.73	88.07
	Female	69.33	78.69	87.81
	Total	139.34	158.42	175.88
Literacy percentage	Male	39.14	67.40	75.92
	Female	37.16	49.54	62.16
	Total	38.16	58.52	69.04
Density in sqkm		414	469	4.66
Sex ratio*		997	995	997
		AESR 8.2		
Population (lakhs)	Male		116.82	136.43
	Female		110.74	130.12
	Total		227.56	266.54
Literacy percentage	Male	58.0	66.6	69.0
	Female	34.7	45.2	54.6
	Total	46.4	56.2	62.0
Density in sqkm			282	331
Sex ratio*			948	954
		AESR 8.3		
Population (lakhs)	Male	154.70	179.82	199.20
	Female	150.97	174.84	196.21
	Total	305.67	354.66	395.41
Literacy percentage	Male	56.88	60.52	68.69
	Female	31.10	39.92	52.53
	Total	44.15	50.37	60.67
Density in sqkm		331	407	442
Sex ratio*		984	979	985

* Females per 1000 males.

The proportion of rural and urban population over three decades is given in Table 4.35. The rural population had decreased during the period 1991-2001 in AESR 8.1 and AESR 8.3 regions. On the other

Table 4.35: Rural urban population in AER 8

Particulars	1991	2001
	AESR 8.1	
Rural	9828958 (62)	8273349 (47)
Urban	6012817 (38)	9314969 (53)
Total	15841775 (100)	17588318 (100)
	AESR 8.2	
Rural	14603189	16057792
Urban	8152432	10596498
Total	22755621	26654290
	AESR 8.3	
Rural	26595612 (75)	26286285 (66.5)
Urban	8869949 (25)	13255142 (33.5)
Total	35465561 (100)	39541427 (100)

Note: Figures within the parentheses indicate decadal change in percentage

hand the urban population increased over the years. It was mainly due to shift of working population from agriculture sector to industrial and other service sectors. But in AESR 8.2 both rural and urban population had increased simultaneously. Disadvantaged section of population is presented in Table 4.36.

In the case of disadvantaged sections, both the SC and ST population in rural and urban population was found increased over the decades in AESR 8.1 and AESR 8.3 regions. This increase was due to normal population growth. The population of scheduled castes was more in AESR 8.2 (18.2% of the total population) than that of scheduled tribes (4.4% of the total population).

Table 4.36: Disadvantaged sections in AER 8

Particulars		AESR 8.1		AESR 8.2	AESR 8.3	
		1981	1991	1991	1981	1991
Scheduled caste	Rural	1588607	1883233		5431168	6444024
	Urban	486039	600809		792391	1039907
	Total	2074646	2484042	4135567	6223559	7483931
Scheduled tribes	Rural	47306	50437		408071	437198
	Urban	11311	18756		27291	35262
	Total	58617	68756	992051	435362	472460

Occupational pattern

The occupational pattern of a region provides an idea about the proportion population working in various sectors. This in turn shows the growth potential of a particular sector.

It was observed that cultivators group reduced in both the sub-regions (Table 4.37). On the other hand, agricultural labour population had increased in these regions. This could be due to the reason that the small and marginal farmers might have gone as labourers for their daily income. Livestock population and mining workers population had increased over the decades. Manufacturing in household and other services population had decreased over the decades, on the other hand, manufacturing in other than household increased. Overall, total workers population had increased and no-workers population had decreased.

Table 4.37: Occupational pattern in AESR 8.1 and 8.3

Particulars	AESR 8.1				AESR 8.3			
	1981	%	1991	%	1981	%	1991	%
Main workers	5741948	100	6736218	100	12129981	100	14610061	100
Cultivators	1256138	21.8	1218638	18.1	4294502	35.4	4433647	30.3
Agricultural Labour	1956797	34.1	2422809	35.9	4065093	33.5	5448295	37.2
Livestock			161254	2.4			141249	0.9
Mining			13005	0.2			54469	0.4
Manufacturing in household	337453	5.9	315100	4.7	543875	4.4	479626	3.3
Manufacturing in other than household			936874	13.9			1164746	8.0
Other services	2191560	38.2	1668538	24.8	3226511	26.6	2888029	19.8
Marginal workers	241349		287412		912907		1098721	
Total workers	5983297	43.0	7023630	44.0	13042888	42.7	15708782	44.3
Non workers	7950841	57.0	8818145	56.0	17524260	57.3	19756779	55.7
Population	13934138	100	15841775	100	30567148	100	35465561	100

The occupational pattern of this region as per 2001 census is furnished in Table 4.38. Out of total population, population of the main workers was 38% and that of marginal workers, 4.5%. The working population was high in rural areas compared to that in the urban areas.

Table 4.38: Occupational pattern of AESR 8.2

(Per cent)

Particulars	Main workers	Marginal workers
Rural	40.6	2.6
Urban	31.1	0.74
Total	38.1	4.5

Note: Reference year 2001.

Health

It was found that the facilities under healthcare had increased over the years (Table. 4.39). The number of beds had increased nearly two-fold, population per bed had reduced over half a time, total doctors had increased four-times during the last decade and population per doctor was reduced to one-third in both the regions.

Table 4.39: Healthcare details of AESR 8.1 and 8.3

Particulars	1991	2001
AESR 8.1		
Population	15841775	17588318
Total beds	6093	13605
Population per bed	2600	1293
Total doctors	675	2449
Population per doctor	23469	7182
AESR 8.3		
Population	35465561	39541427
Total beds	14603	23550
Population per bed	2429	1679
Total doctors	1607	4815
Population per doctor	22069	8212

The hospital facilities and the development of healthcare facilities in the AESR 8.2 are presented in Tables 4.40 and 4.41.

Over the decades, the number of beds per lakh population had increased; the population growth was higher than to the increase in the number of government medical institutions. The healthcare has improved during the past three decades as evidenced from Table 4.42 and Table 4.43.

Table 4.40: Hospital facilities in AESR 8.2

Hospitals	Number	Beds
State government	72	12693
Other agencies	53	4842
Indian system of medicine	43	866
Primary health centre	821	8187
Primary health unit	433	740
Dispensaries	120	22
Dispensaries coming under Indian system of medicines	311	
Family welfare Centres	222	
Sub-centres	3921	

Note: Reference year 1997/98.

Table 4.41: Development of healthcare facilities in AESR 8.2

Year	Population per government medical institution	No. of beds per lakh population
1960-61	13638	58
1970-71	17528	83
1980-81	16923	79
1990-91	17414	114
1996-97	16844	92

Table 4.42: Birth rates and death rates in AESR 8.2

Year	Estimated crude birth rates	Estimated crude death rates
1951-61	41.5	19.5
1961-71	38.2	14.6
1971-81	32.7	10.6
1981-91	29.1	9.5
1990-91	27.2	8.3

Table 4.43: Life expectancy and infant mortality rate in AESR 8.2

Year	Life expectancy at birth (years)			Female infant mortality rate (%)
	Males	Females	Persons	
1981			58.3	68.1
1991	60.8	66.8	63.7	55.6

The birth rates and death rates had reduced over the years. The female infant mortality rate was reduced from 68.1% in 1981-91 to 55.6% in 1990-91. The life expectancy had increased from 58.3 years during 1981 to 63.7 years in 1991, due to improved healthcare facilities in the region.

Consumption and Nutrition

There is a synergistic relationship between poverty, malnutrition and ill health. Each feeds on the other in a circular constellation. The per capita calorie intake indicates the purchasing power and consumption pattern of the people.

It was found that rural per capita calorie intake had increased from 38th round to 50th round in AESR 8.1 and AESR 8.3. But in urban areas the calorie intake had decreased drastically. In case of average per capita calorie intake, it reduced from 2000 to 1903 kcal in both the regions. In case of AESR 8.2, both the rural and urban per capita calorie intake had decreased from 38th round to 50th round in the region. But it had increased in the 55th round noticeably. In the case of average calorie intake per consumer unit was lower in urban area compared to that in the rural area.

Table 4.44: Per capita calorie intake in AER 8

(kcal)

AESR	Rural		Urban		Average		
	38th round (83-84)	50th round (93-94)	38th round (83-84)	50th round (93-94)	38th round (83-84)	50th round (93-94)	55th round (99-01)
8.1	1821	1884	2179	1922	2000	1903	1812
8.2	2204	2073	2143	2026	2714	2050	2087
8.3	1821	1884	2179	1922	2000	1903	1909

It was also evidenced that protein and fat consumption level was below the national level in both the regions (Table 4.45). At the national level, protein intake was 75 g in rural and 70.2 g in urban and fat consumption was 39.1 g in rural and 51.6 g in urban areas.

Table 4.45: Average per capita nutrient intake in AER 8

Particulars	Rural	Urban
Calorie (kcal)	2347	2366
Protein (gram)	58.3	60
Fat (gram)	30.7	41.8

Infrastructure

Infrastructure development of any region is crucial for the development of different sectors like agriculture, industry etc. Keeping these in view, the details on various infrastructure facilities of the study regions were also studied.

Markets

The Government has built up an extensive network of Regulated Markets and Cooperative Marketing Societies in the study region. Although the quantity of agricultural produce transacted in the Regulated Markets has been increasing over time, the proportion of agriculture produce marketed through Regulated Markets was not very significant. Keeping this in mind, yet another scheme viz. Uzhavar Santhai (Farmers Market) was introduced during 1999 in ASER 8.1 and ASER 8.3. The main objective of this market is to ensure remunerative prices to the farmers, to eliminate middlemen and to enable the consumers to get vegetables and other perishables at reasonable prices.

Table 4.46: Regulated markets in AESR 8.2

Details	Number
Main	60
Sub	129
Total	189
Turnover (Rs. In lakhs)	268453

In AESR 8.2, the markets were found functioning well and the government was making considerable efforts to improve the performance of the markets by giving subsidies to the farmers through various schemes.

Roads and banking

As far the transport and communication is concerned, the regions were found having well developed facilities. Almost all the villages in the regions, AESR 8.1 and AESR 8.3, have been electrified. The number of pumpsets energized is crucial in the development agricultural sector. It was evidenced that the number of pumpsets energized was 412004 in AESR 8.1 and 1305777 in AESR 8.3 (Table 4.47). The regions also have fairly developed infrastructure in terms number of banking institutions.

The sub-region AESR 8.2 had well developed transport and communication facilities as shown in Table 4.47. All the districts in the region were well connected by road network and communication network.

Table 4.47: Development of infrastructure facilities in AER 8

Particulars	1980s	1990s	2001
AESR 8.1			
Total road length (km)	3396	2105	
Number of banks	1086	1346	1423
Credit (in lakh Rs)	130306	501958.4	1230493
Pumpsets energised			412004
AESR 8.3			
Total road length (km)	10149	5268	
Number of banks	2060	2435	2517
Credit (in lakh Rs)	158065	492436	1100938
Pumpsets energised			1305777
AESR 8.2			
Total road length as on 31.3.2001 (km)			79838
Major bridges (No.)			147
No. of Post Offices as on 31.3.2002			4345
No. of Telephone Exchanges as on 31.3.2002			1169
No. of Telephones as on 31.3.2002			1605116

Railways

All the districts in these two regions are well connected by railway network of 5578 km length. However at present the road transport accounts for 60% of the freight traffic as against National Transport Policy Committee suggestions. There is a need to convert the metre gauge into broad gauge and doubling of tracks to catalyze industrial and commercial activities of these regions.

Electrification

Use of power has been increasing at a faster rate for domestic and agricultural purposes than for commercial and industrial use. It was found that almost all the villages in both regions were electrified (Table 4.48). As power is free of cost to agriculture, the consumption of power has been increasing in this sector. In future power consumption in this sector may stabilize as the Government has planned to charge the power in coming year.

Table 4.48: Electrification in AER 8

(numbers)

Electrification	AESR 8.1	AESR 8.3
Pumpsets energized	412004	1305777
Towns existing	153	268
Towns electrified	153	268
Villages existing	2962	12826
Villages electrified	2956	12823

Industries

District-wise analysis of the Annual Survey of Industries 1997-98 has shown that Coimbatore district in AESR 8.1 tops the list in number of industries in operation. A majority of registered industries belongs to the small-scale category and account for 50.4% in the total number of registered industries. It could be seen from the Table 4.49 that the process of industrialization is picking up well after 1990s. The number of industries has increased nearly two fold in AESR 8.1 region and one and half fold in AESR 8.3 region.

Table 4.49: Industries in AESR 8.1 and 8.3

Year	Number of industries	
	AESR 8.1	AESR 8.3
1980-81	3511	5350
1990-91	6169	7526
1994-95	8050	9020

The number of small-scale industrial units in AESR 8.2 the year 1998 was 16004, and the number of persons employed was 71063. The phase of industrialization is little bit slow but during the past five years the growth of industries is on the expected lines, particularly in the field of information technology. The number of cumulative industrial units was 123668 with employment of 787086 persons.(Table 4.50)

Table 4.50: Small scale industrial units set up in AESR 8.2

During the year 1997-98	Units	16004
	Employment	71063
Cumulative	Units	123668
	Employment	787086

Credit

The study on the banking in the region AESR 8.2 (Table 4.51) revealed that it had fairly developed infrastructure in terms number of banking institutions both commercial and co-operative banks.

Table 4.51: Type of banks and credit details in AESR 8.2

Particulars	Numbers
Banks as on 31.3.2002	
Commercial banks	1992
Graneena banks	461
Total deposits (lakh Rs.)	4369730
Total credits (lakh Rs.)	2793460
Credit Co-operative Societies as on 31.3.2001	
Agriculture	1821
Non-agriculture	1174
Total	2995
Non-Credit Co-operative Societies as on 31.3.2001	
Marketing	161
Housing	743
Milk	6156
Others	4669
Total	11729
P.L.D.Banks as on 31.3.2002	
Number	84
Total loans (lakhs Rs)	12215
Co-operative Banks (urban) as on 31.3.2001	
Main offices	122
Branches	304
Deposits (lakhs Rs)	204936
Loan advanced (lakhs Rs)	137834
Other Co-operative Banks as on 31.3.1997	1016

Watershed development activities

The Central Water Commission has identified Coimbatore, Madurai, Dindigul, Kanyakumari and Tirunelveli districts in AESR 8.1 and Ramanathapuram, Salem, Trichy, Erode and Dharmapuri districts in

AESR 8.3 as drought prone districts. In order to improve water resources, watershed projects are being implemented in these regions under Drought Prone Area Programme (DPAP) and National Watershed Development Project for Rainfed Areas (NWDPRA) schemes. The Forest Department also has implemented watershed development programmes through Joint Forest Management plan from 1997 onwards.

Production Planning and Water Management

The area under cereals has declined but productivity of cereals particularly rice has improved at national level. The demand and supply balance of various crops is presented in the Table 4.52. It could be seen from the Table that there exists demand supply gap in all crops for the year 2000 and 2010.

Table 4.52: Food demand-supply balance

(lakh tonnes)

Crop	Year 2000	Year 2010
Rice	–15.4	–13.7
Greater millet (Cholam)	–2.2	–1.8
Pearl millet (Cumbu)	–0.63	–1.0
Maize	–0.3	1.4
Finger millet (Ragi)	–1.1	–1.6
Cereals	–17.2	–19.1
Pulses	–13.8	–14.2
Food grains	–31.4	–34.3
Sugar	14.0	33.9
Fruits	18.5	23.3
Vegetables	–66.8	–67.6
Oilseeds	–2.8	–2.1
Cotton	–16.0	–15.9

To fill the demand-supply gap, the required productivity and the growth rates for the AESR 8.1 and AESR 8.3 are presented in the Table 4.53.

Among the food crops, pulses and oilseeds productivity level has to improve with three-fold growth rate. In future, efforts are needed to achieve higher productivity in these crops.

Table 4.53: Existing productivity and required productivity to fill the demand-supply gap

Crop/category	Existing productivity (tonnes/ha)		Required productivity (tonnes/ha)		Percentage growth required			
					Over mid ninety		Over highest achieved	
	Mid-ninety	Highest achieved	Year 2000	Year 2010	Year 2000	Year 2010	Year 2000	Year 2010
Rice	2.9	3.1	3.8	4.7	4.6	3.1	3.5	2.7
Greater millet (Cholam)	0.9	1.2	1.3	1.5	5.5	2.9	1.9	1.6
Pearl millet (Cumbu)	1.1	1.4	1.5	2.2	4.4	4.2	0.2	2.6
Maize	1.6	2.5	3.2	3.5	12.3	4.9	4.6	2.2
Finger millet (Ragi)	2.1	2.1	3.7	7.0	9.7	7.8	9.7	7.8
Cereals	1.31	1.31	1.65	2.29	3.92	3.55	3.92	3.55
Pulses	0.41	0.47	2.13	2.04	31.60	10.55	28.64	9.61
Food grains	1.91	2.12	2.96	3.55	7.57	3.95	5.72	3.27
Total oilseeds (nuts in shell)	1.38	1.38	2.19	2.30	8.00	3.24	8.00	3.24
Sugarcane	104.0	107.00	61.58	57.42	-	-	-	-
Fruits	17.01	17.86	9.92	9.65	-	-	-	-
Vegetables	4.27	5.40	44.51	43.48	47.80	15.61	42.13	13.92

Water and food security issues and prospects

Though there are about 17 river basins in AESR 8.1 and AESR 8.3, only few basins are surplus in water supply. The demand supply gap of water for 2025 in these AESRs is given in Table 4.54.

The supply-demand gap was found more in the agricultural sector, nearly 45%. Increasing competition for water resources from other sectors too posing a challenge on the intersectoral allocation of available water.

Table 4.54: Supply - Demand gap for water in 2025

Particulars	Quantity in MHM	%
Total water supply	4.7	
Demand for water		
Agricultural	5.2	75.9
Non Agricultural	1.6	24.1
NCA (Revised estimates)		
Agricultural	3.8	69.7
Non Agricultural	1.6	30.3
Supply - Demand gap		
Agricultural	2.1	44.7
Non Agricultural	0.7	14.9

The major issues in water and food security are:

- The area under cereals has been declining over years. Apart from this, the productivity of the irrigated cereals was 2.8 tonnes in AESR 8.2, 4.2 tonnes in AESR 8.1 and 3.4 tonnes in AESR 8.3 respectively. It may be due to reason that the irrigated area under cereals in this region is nearly 38% (2000-01). The irrigated productivity should be 6 tonnes per ha to balance the demand and supply of foodgrains in future.
- As more than 60% of cereal area is under rainfed, efforts should be made to improve the productivity of rainfed cereals.
- The productivity of pulses and oilseeds is below the national average.
- The efficiency of the irrigation systems of both surface and ground water is less in AESR 8.2, compared to the other sub-regions.

- The endowed irrigation potential in per capita terms at 0.08 ha is much lower than the national average of 0.17 ha.
- Efficiency of the irrigation systems has to be improved.
- The proliferation of wells and indiscriminate exploitation of groundwater for irrigation and drinking water has affected groundwater table in these regions. It has led to an imbalance between the rate of withdrawal and rate of recharge of groundwater, which needs to be set right.

Some of the possible ways to tackle the problems are:

- By stepping up the irrigation efficiency in stages between 20 and 60 % in the modernized command area the irrigation demand for the future has to be assessed.
- Extensive investigation is required to determine the sustainable exploitation rate of groundwater and inter sectoral allocation of water.
- Reforms on water rights, the privatization of utilities, and laws pertaining to water user associations, market-based incentives, which directly influence the behaviour of water users by providing incentives to conserve on water use, including reduced subsidies on urban water consumption.
- Water resource development includes rehabilitation of canals in command areas, rehabilitation of irrigation tanks, increasing area under minor irrigation through wells and popularization of micro-irrigation (drip and *biwall*) systems.
- The demand for drinking water in the urban and rural areas will increase in the coming years. This demand cannot be met entirely from groundwater sources. In about 1000 villages, groundwater is not fit for drinking purposes on account of high fluoride or iron content or brackishness in this region. Therefore, in the next two decades water supply systems for larger habitations will have to be based on surface water sources like perennial rivers and reservoirs and reduction in the irrigation water use may be inevitable.
- Productivity of irrigation is below potential. Sub-optimal distribution of water and lack of integration of irrigation services with agriculture services have resulted in low yields, low cropping

intensities and has prevented diversification of agriculture. Land development and agricultural extension have not kept pace with the creation of irrigation potential.

- Irrigation planning should take into account the irrigability classification of land, cost-effective irrigation techniques and the needs of drought prone and rain-shadow areas. Wherever water is scarce, the irrigation intensity will be such as to extend the benefits of irrigation to as large an area as possible in order to maximize production. Land and water are mutually reinforcing resource systems, which are limited in the state. Land-use pattern has perceptible influence on the hydrological characteristics, the soil erosion factors and soil is non-renewable and irreplaceable beyond a certain point of damage. Water availability is limited but its irrational and overuse has resulted in low overall project efficiencies and considerable land degradation. The management of water and land resources and water and land-use planning and management are closely intertwined and hence, there should be close integration of water-use and land-use policies.

- Appropriate cropping patterns should be adopted in co-ordination with the Agriculture Department. Drip and sprinkler irrigation to improve water use efficiency should be promoted. Irrigation and multi purpose projects should invariably include drinking water component.

- The management of water resources should be done adopting a participatory approach. Necessary legal and institutional changes would be made. The ultimate goal should be to transfer operation, maintenance, management and collection of water charges to user groups.

- Water rates for various uses could be revised in a phased manner and fixed so as to cover at least the operational and maintenance charges for providing services.

V. Resource Characterization for Sustainable Agriculture Development in AER 12

H.N. Verma, R.B. Singandhupe, P. Nanda, G. Kar and D.K. Panda

Introduction

The AER 12 (major parts of eastern India) receives higher average annual rainfall, ranging from 900 to 1700 mm, but due to lack of appropriate water and soil management, the region has one of the lowest agricultural productivities of the country. The region is mostly rainfed and subject to recurrent droughts. Poor socio-economic conditions resulting from low agricultural and animal productivity in this region remain a matter of concern for researchers and policy makers. It is forecasted that the eastern part of the country would face severe food insecurity and indicators of quality of life would deteriorate. Rainwater being excess in *kharif* and deficit in *rabi* seasons impedes input utilization for agricultural growth. In some parts of this region, high intensity of rainfall within a short span of time creates inundation and damages crop growth during the south-west monsoon period (June to September) and the saucer-shaped topography does not allow the run-off to be drained soon in some of the coastal tracts, creating seasonal waterlogging. The agricultural droughts of varying intensities on the other hand, limit the crop production potential in other seasons. Due to these multiple problems, the agricultural productivity of the region is very low.

Crop husbandry alone is inadequate so as to support the livelihoods of the people. Fisheries and livestock available as alternative sources of income to the people are yet to be explored economically. Tribal population in the region constitutes 40% of total population with low level of literacy, high infant mortality rate, low level of crop and animal husbandry productivity. The demographic characteristics of the region are reflected by average level of literacy (60.2%), gender ratio of 969 female per 1000 male and population density of 363 people per square kilometre.

Location

The AER 12 covers a total area of 26.8 M ha comprising of 31 districts of six states (Orissa, Jharkhand, West Bengal, Chattisgarh, Maharashtra and Andhra Pradesh). It constitutes whole of undivided 13 districts of Orissa (eastern ghat highlands, coastal alluvial tract, table land), eastern part of Jharkhand, south-east West Bengal, northern Andhra Pradesh, one district of Chattisgarh and two districts of Maharashtra. The region accounts for 8.1% of total geographical area of the country (Table 5.1). Based on agro-climatic and edaphic characteristics, the region has been divided into three agro-ecological sub-regions namely AESR 12.1 (Garjat Hills, Dandakaranya and Eastern Ghats), AESR 12.2 (Eastern Ghats) and AESR 12.3 (Chhotanagpur Plateau, Garjat Hills). Red laterite soil type is predominant throughout the region with small area under coastal alluvial (flood plain) in Orissa and northern Andhra Pradesh. The major river basins like the Mahanadi, the Godavari, the Bansadhara, the Indravati, the Brahmani, the Baitarani and the Subernarekha contribute to water availability in the region and define the drainage pattern.

Table 5.1: Geographical coverage of AER 12

Agro-ecological Classification	Total area (M ha)	Per cent of AER 12	Per cent of the TGAC#	Districts
AESR 12.1				
Garjat Hills, Dandakaranya, Eastern Ghats (hot, moist-sub-humid)	17.9	66.8	5.4	Koraput, Bolangir, Sambalpur, Sundargarh, Dhenkanal, Kalahandi, Mayurbhanj, Phulabani, Chandrapur, Gadchirolli, Baster, East Godavari
AESR 12.2				
Eastern Ghats, (hot, moist-sub-humid)	3.3	12.3	1.0	Visakhapatnam, Vijaynagaram, Ganjam, Puri, Cuttack, Balasore
AESR 12.3				
Chhotanagpur Plateau, Garjat Hills, (hot, dry-sub-humid)	5.6	20.9	1.7	Ranchi, Dhanbad, Dumka, Giridih, Deoghar, Singbhum (east & west), Sahibganj, Purulia, Birbhum, Bankura, Midnapur, Keonjhar.
AER 12	26.8	100	8.1	

#TGAC = Total Geographical Area of the country
Source: National Bureau of Soil Survey & Land Use Planning, Publication No. 35, ICAR, New Delhi. 1999

Land Use Pattern of AER 12

The land use pattern of different AESRs of AER 12 are given in Table 5.2 which depicts that the net sown area of the region is 36% of its total geographical area. Barren land and uncultivable waste cover 4.7% and 4.3% of the geographical area, respectively. Forest covers 34% of the geographical area of AER 12 as against 20.4% for the country. The average cropping intensity of the region is about 118%, with the highest (133%) in AESR 12.2. The cropping intensity of AESR 12.1 is 110% and that of AESR 12.2 is 112% (Table 5.3).

Table 5.2: Land use pattern of AER 12

(Per cent)

Land-use	AESR 12.1	AESR 12.2	AESR 12.3	AER 12
Geographical area (M ha)	17.9	3.3	5.6	26.8
Net sown area	29	41	38	36.0
Forests	53	26	24	34.3
Barren lands	2	6	6	4.7
Uncultivable waste	2	4	7	4.3

Source: National Bureau of Soil Survey & Land-use Planning, Publication No. 35, ICAR, New Delhi, 1999.

Table 5.3: Cropping intensity and fertilizer use in AER 12

Parameter	AESR 12.1	AESR 12.2	AESR 12.3	AER 12
Cropping intensity (%)	110	133	112	118.3
Fertilizer consumption (kg/ha)	63	72	50	61.7

Based on hydrology and topography of land, cultivated area of the region has been divided into different ecologies, viz. rainfed uplands (no ponded water), rainfed low lands [shallow (5-25 cm water depth), intermediate (25-50 cm water depth), semi-deep and deep (50-100 cm water depth)] and irrigated. The AESR-wise land-use pattern is discussed below.

AESR 12.1

In this sub-region forest covers 53% of total geographical area followed by net sown area (29%). Barren and uncultivable waste each constitutes 2% of total geographical area of AER 12 (Table 5.2). The region is characterized by normal growing period from June to October with July, August and September as humid months. Main growing seasons in the region are *kharif* (June to October) and *rabi* (November/December to March/April). The average cropping intensity of this AESR is 110%, indicating dominance of single cropping system. Rice, maize, groundnut, blackgram, jowar, etc. are the dominant rainfed upland crops whereas rice is the only crop in lowlands during the *kharif* season. During the *rabi* season, pulses (blackgram, greengram, lathyrus) and oilseeds (sesamum, niger, mustard) are grown, utilizing residual soil moisture or limited irrigation. In districts like Koraput and Phulbani of Orissa, Jhum (slash and burn type) cultivation is in practice.

AESR 12.2

This sub-region has a total geographical area of 3.3 M ha. Net sown area accounts for 41% of the total area of sub-region followed by forests (26%). Area under barren and uncultivable waste is 6 and 4%, respectively. Fertiliser consumption (72 kg/ha) is more in this sub region as compared to other two sub-regions (Table 5.3). The agro-economic condition of the region is driven by rice-based cropping system. Vegetables, groundnut, wheat are grown during *rabi* where assured irrigation exists in this sub-region.

AESR 12.3

Tribal people with subsistence traditional agricultural practices dominantly inhabit this region. Total geographical area is 5.6 M ha of which net sown area is about 2 M ha (38%) and Forest area is 24%. The rice-fallow cropping system is most prevalent in this sub-region. Rice of different durations are taken up in different rice ecologies, viz. up, medium and low lands. In this region, some of the major non-rice *kharif* crops are maize, jute, niger, ragi, and pigeon pea. Vegetables are taken in small area under assured irrigation during the *rabi* season.

Agro-climatic characteristics

The agricultural planning of the region should consider the variability in the amount, distribution and onset of monsoon, thermal environment, evaporative demand of atmosphere and crops, etc. Since in AER 12, agriculture is mainly dependent on the performance of south-west monsoon rainfall, crop planning is decided by its onset, withdrawal and a slight delay in sowing of rainfed crops may lead to drastic reduction in yield. The rainfall and evapotranspiration ultimately determine water balance and crop water requirements, the studies of which are helpful to characterize the earliest probable sowing time, defining risk levels in arable agriculture, characterizing length of growing period and cropping system in the rainfed ecosystem. Two major climatic zones viz. moist sub-humid and dry sub-humid zones exist in AER 12.

Rainfall distribution and variability

The seasonal distribution of rainfall in different AESRs of AER 12 has been computed and is presented in Table 5.4. It was revealed that 66.1 to 80.8% of the total annual rainfall occurred during south-west monsoon period in different AESRs of the region (Table 5.5). Pre-monsoon showers contributed 7.6 to 8.5% of total annual rainfall, and are of special significance for performing off-season tillage operations and land

Table 5.4: Seasonal distribution of rainfall in AER 12

(mm)

AESRs	Pre monsoon (March to May)	Monsoon (June to Sept.)	Post monsoon (Oct to Nov.)	Winter (Dec to Feb)	Annual Total
12.1	114	1182	150	36	1488
12.2	111	898	306	42	1358
12.3	113	1074	118	45	1329
AER 12	112	1051	191	41	1392

Source: Climatological Table, IMD, New Delhi, 1951-1980.

Table 5.5: Rainfall in different seasons as percentage of annual total

(Per cent)

AESRs	Pre monsoon (March to May)	Monsoon (June to Sept.)	Post monsoon (Oct to Nov.)	Winter (Dec to Feb)	Annual Total rainfall (mm)
12.1	7.6	79.4	10.1	2.4	1488
12.2	8.1	66.1	22.8	3.1	1358
12.3	8.5	80.8	8.9	3.4	1329
AER 12	8.1	75.4	13.4	2.9	1392

Source: Climatological Table (1951-1980), IMD, New Delhi.

preparation for upland crops or seedbed preparation for rice in the region. Farmers are advised to perform off-season tillage and prepare land with pre-monsoon showers, so that they can sow the low duty direct seeded crops in upland soils immediately with the onset of south-west monsoon. Besides, off-season tillage improves water retention capacity of soils and reduces weed, pest and disease infestation. During post or retreating monsoon period (October-November), 8.9 to 22.8% of the annual rainfall occurs in different AESRs of AER 12 (Table 5.5). Among different districts, East Godavari district of AESR 12.1 and Visakhapatnam district of AESR 12.2 receive higher rainfall during post-monsoon period (25.2% and 35.8% of total annual rainfall, respectively). This post monsoon rainfall can play a very crucial role in sowing and establishment of second short-duration, low-water requiring pre-winter crops like horsegram, sesamum, niger, etc. in rainfed uplands after harvesting of first crops like maize, short duration rice etc. It will also be helpful for a better growth and development of medium and long-duration rice in rainfed low land rice ecosystem.

Regarding coefficient of variability (CV) of monthly rainfall over time (Table 5.6), the lowest variability was observed during south-west monsoon period (June to September) particularly in the month of July (18-32%) and August (23-31%). In general, from the monthly variability of rainfall, it could be concluded that rainfall during south-west monsoon

Table 5.6: Coefficient of variability of monthly rainfall

(per cent)

Month	AESR 12.1		AESR 12.2		AESR 12.3	
	Min	Max	Min	Max	Min	Max
Jan	162	243	152	210	118	211
Feb	134	160	120	147	93	145
Mar	104	274	103	141	96	131
Apr	67	109	68	94	52	92
May	64	107	78	121	44	68
Jun	41	56	39	47	11	44
Jul	23	43	32	34	18	24
Aug	29	42	31	37	23	28
Sep	20	131	35	40	34	73
Oct	73	114	67	85	72	99
Nov	153	213	145	177	117	172
Dec	223	391	234	319	176	330

Note: Reference year 1951 onwards.

period (*kharif* season) was less variable and rainfed crops could successfully be grown. Winter rainfall was highly variable and meagre; growing of high value *rabi* crops during winter season without irrigation support could be risky.

Cold requiring crop zoning

The key ecological characteristics of cold requiring crops like wheat, mustard, potato, gram, etc. are general adaptation of its photosynthetic and growth process to daily mean temperatures in the range of 15-19 °C and minimum temperatures of 10-14 °C. The interactions between genotype and environment, principally temperature and day length determine the phenology and productivity of cold requiring crops. In the AER 12, which comprises mainly Orissa, West Bengal, Jharkhand and Chattishgarh, the farmers cultivate cold requiring crops inspite of not getting net positive economic return. It may be due to the existence of unfavourable thermal environments for growing these crops.

Hence an attempt was made to analyse thermal regime of AER 12 for finding feasibility of growing cold requiring crops commercially with good net economic return. In this study, the number of weeks of existence of favourable mean temperatures of 15–19 ^{0}C and minimum temperatures of 10–14 ^{0}C were identified and were mapped into 4 zones using ARCVIEW GIS software (ESRI, 1998). The study revealed that optimum mean favourable temperature of 15-19 ^{0}C and minimum temperature of 10-14 ^{0}C prevails for 7-10 weeks in AESR 12.1, for 1-3 weeks in AESR 12.2 and for 6-7 weeks in the AESR 12.3. It is also found that in AESR 12.3, favourable mean and minimum temperatures for growing cold requiring crops existed up to 04 standard meteorological weeks (last week of January), which coincided with flowering stage of wheat, mustard, gram etc. and tuber initiation stage of potato. But, during the pod formation stage of pulses and oilseeds, grain filling stage of wheat and tuber bulking stage of potato (05-08 standard meteorological weeks, first week of February onwards), minimum temperature increases abruptly which restricts the accumulation of photosynthesis towards economic part of these cold requiring crops because of higher respiration. As a result, these crops record low productivity in AESR 12.3. Therefore, based on the availability of favourable thermal regimes, the cold requiring crops may be grown in districts of AESR 12.1, particularly in Mayurbhanj, Sambalpur, Bolangir, Phulbani, Baster, etc. But, before initiating commercial cultivation of these crops economic feasibility should be studied.

Monthly rainfall at different probability levels

The probable date of onset of southwest monsoon was 23rd (4-10th June) to 24th (11-17th June) standard meteorological weeks in different AESRs of AER 12 and length of growing period starts from 23rd standard week as per climatic water analysis. So sowing operation of direct seeded upland crops can be initiated from this week but prediction of monsoon (south-west) rainfall is also of paramount importance for raising crop successfully with high and stable yield. In this study, monthly rainfall during south-west monsoon period (June to September) was predicted at 80% probability (highly assured level) using Extreme Value Distribution Type-1 probability model. The study revealed that in the first monsoon month (June), 98 to 156 mm rainfall (average 121 mm) occured at 80% (most dependable limit) probability level in AESR 12.1, 103 to 144 mm (average 122 mm) in AESR 12.2 and 93 to 132 mm (average 114 m) in AESR 12.3 (Table. 5.7). So the rainfall at dependable level during June could be utilized for rainfed upland crop planning. Direct seeded crops namely groundnut, pigeonpea, cowpea, maize and black gram could be sown and rice nurseries could be prepared in 23rd (4-10th June) to 24th (11-17th June) weeks with the commencement of south-west monsoon in the region. In the month of July at 80% probability level, 216 mm to 222 mm (average of 247 mm) in AESR 12.1, 193 mm to 222 mm (average 197 mm) in AESR 12.2, 190 mm to 235 mm rainfall (average 205 mm) in AESR 12.3 was predicted. This amount of rainfall could be utilized for rice transplanting starting from first fortnight of July in medium and low land rice ecosystems. The transplanting *of kharif* rice in the first week of July would have additional advantage of assured rain during August and September.

Table 5.7: Prediction of south-west monsoon rainfall at 80% probability

(mm)

Month	AESR 12.1	AESR 12.2	AESR 12.3	AER 12
Jun	121	122	114	119
Jul	247	197	205	216
Aug	232	228	208	223
Sep	142	157	136	145

Note : Average was calculated based on arithmetic mean of different districts
Rainfall data (1960 to 2002); Source: Revenue Department, Cuttack and IMD, Pune

To increase the rainwater-use efficiency and productivity of light-textured uplands, rice can be substituted with other low water requiring crops like maize, groundnut, pigeonpea and cowpea through sole or intercropping. In case maize, groundnut, pigeonpea or direct seeded rice based inter-crops could not be sown by the end of June or fail to establish in June due to dry spell or aberrant weather, then black gram, cowpea and sesamum could be sown up to the last week of July. Maize, groundnut or upland rice-based intercropping may not be sown if aberrant rainfall continues up to the middle of July because delayed sowing of these crops might cause crop failure or very low productivity. Since the rainfall after October is uncertain and erratic, sowing of high value *rabi* crops without supplementary irrigation is not feasible during winter season.

Climatic water balance and length of growing period

The climatic water balance parameters viz. actual evapotranspiration, surplus water and length of growing period (LGP) were computed using Thronthwaite and Mathers' (1957) bookkeeping procedure, considering the average available water capacity is 150 mm. Such a study would be useful for assessing water harvesting potential of the region. The climatic water balance of AESR 12.1 revealed that large-to-moderate water surplus (500-600 mm) occurred during the humid (P > PET) months of July to September and thereafter monsoon rainfall ceased in October. This sub-region is characterized by normal growing period with June and October as moist months and July, August, September as humid months and November and December as moderately dry months. The LGP ranges between 150-200 days, starting from 23rd standard week and ends in December. In AESR 12.2, moisture availability period begins from end of June and continues up to December. The LGP ranges between 200-250 days, which occurs mainly during four humid months (July to October) and two moderate dry months (November and December). In AESR 12.3 also, moisture availability begins from end of June and continues up to December, the LGP is normal (180 to 210 days) with prominent moist (July to September) and moderate dry periods (November and December). The rainfall surplus of 200 to 350 mm was computed in AESR 12.2 and 350 to 500 mm in AESR 12.3. Since winter rainfall was meagre and erratic, this amount of rainfall might be harvested and utilized for providing supplementary irrigation to *rabi* crops or during dry spells to *kharif* crops.

Reference crop evapotranspiration and crop water requirements

The evapotranspiration rate from a reference surface, not short of water, is called the reference crop evapotranspiration or reference evapotranspiration and is denoted as ET_0. The crop evapotranspiration under standard conditions, denoted as ET_c, is the evapotranspiration from disease-free, well-fertilized crops, grown in large field under optimum soil water conditions and achieving full production under the given climatic conditions (Allen *et al.*, 1989). The ET_c can be calculated from the climatic data and by integrating directly the crop resistance, albedo or air resistance factors using empirical equations. Several researchers have analysed ET_0 at different locations by using different empirical formulae. Among them, FAO Penman-Monteith method is now recommended as the standard method for definition and computation of ET_0 (Allen *et al.*, 1998). The ET_c is calculated by multiplying the ET_0 with a crop coefficient, K_c.

In this study, the ET_0 was estimated by using FAO Penman-Monteith equation using CROPWAT 4.0 simulation model. As expected, ET_0 was highest in the month of May for all the stations due to higher evaporative demand and radiation (Table 5.8), and the lowest value was observed during winter season.

Table 5.8: Reference crop evapotranspiration in AER 12

(mm)

Month	AESR 12.1		AESR 12.2		AESR 12.3	
	Min	Max	Min	Max	Min	Max
Jan	77	108	93	124	75	90
Feb	87	137	104	129	82	104
Mar	136	195	167	184	136	164
Apr	156	240	159	201	135	210
May	170	280	166	220	178	224
Jun	132	213	150	183	142	165
Jul	93	139	115	147	110	118
Aug	99	146	118	145	109	121
Sep	93	111	111	132	105	114
Oct	103	133	118	146	87	127
Nov	78	108	96	128	79	92
Dec	71	105	84	122	67	84

Note : Results based on Climatic data obtained from Climatological Table, IMD, New Delhi, 1951-80.

The water requirements of important *kharif* crops like rice, blackgram, maize, groundnut and of *rabi* crops like greengram, winter groundnut, winter maize, wheat, etc. were computed for different AESRs of AER 12 to explore the possibility of cultivation of these crops under rainfed conditions and to stabilize productivity of winter crops utilizing limited irrigation, Mean results of different AESRs are given in Table 5.9.

Table 5.9: Water and irrigation requirement of crops in AER 12

(mm)

Crops	Duration (days)	AESR 12.1		AESR 12.2		AESR 12.3	
		CWR	IR	CWR	IR	CWR	IR
Kharif crops							
Rice (autumn)	90	424	36	535	134	481	50
Maize	90	307	0	348	46	309	0
Blackgram	90	335	0	375	37	337	0
Groundnut	120	399	0	463	46	400	0
Pigeonpea	145	449	15	541	44	448	10
Grrengram	90	334	0	376	37	337	0
Sesamum	85	196	0	228	0	192	0
Rabi crops							
Blackgram	105	256	227	346	296	264	207
Greengram	105	266	237	345	299	266	212
Groundnut	120	352	317	454	399	367	301
Maize	90	241	217	326	293	250	199
Wheat	120	362	326	457	407	279	312
Summer crops							
Summer rice	120	685	614	752	668	717	615

Crop coefficient data source: Doorenbos & Pruitt, 1977

The study revealed that under normal rainfall year among different *kharif* crops (direct seeded), autumn (upland) rice needed irrigation (average 36 to 134 mm) because of its higher water requirements than those of other crops (maize, blackgram, groundnut, pigeonpea, greengram). Since winter rainfall was meagre and erratic, all the *rabi* crops required considerable amount of irrigation in all the AESRs. It is also worthwhile to mention here that crop water requirements of AESR 12.2 were higher for all the crops than those of other sub-regions.

Summing up

Rainwater management

The study of the climatic parameters of AER 12 has vital implications for sustainable agricultural development through diversified cropping systems in rainfed areas. Since agriculture of this region is south-west monsoon dependant, the crop planning is decided by onset and withdrawal of this monsoon. Thus the climatic parameters, particularly rainfall and evaporation, are useful to characterize earliest probable sowing time, defining risk levels in arable agriculture, characterize length of growing period and cropping system in rainfed areas.

Food, nutrition and environmental security

Against the backdrop of increasing population worldover, it is imperative that national food production and policy should receive attention to avoid any food insecurity in future. In this context, crop diversification with cereals, pulses, oilseeds, vegetables, fruits, agro-forestry, etc. through optimal use of rainfall, soil and other natural resources will not only provide food-security but also nutritional and environmental security as well.

Water security through run-off recycling

Rainfall and climatic water balance analysis reveals that there is a lot of scope to harvest rainwater in the region. Since winter rainfall is meagre and uncertain, the run-off water during *kharif* season may be harvested and recycled for providing supplemental irrigation to the second crops during *rabi* season

Increasing soil water retention through off-season tillage

Pre-monsoon showers contribute 7.6 to 8.5% of total annual rainfall, which are of special significance for performing off-season tillage operations and land preparation for upland crops or seedbed preparation for rice in the region. Farmers are advised to perform off-season tillage and prepare land with pre-monsoon showers, so that they can sow the low-duty direct-seeded crops in upland soils immediately with the onset of south-west monsoon. Off-season tillage improves water retention capacity of soils and reduces weed, pest and disease infestation.

Human and livestock resources

Demography

The detailed statistics of growth, density, sex ratio and literacy (1981-91 and 1991-2001) are given in Table 5.10 for different AESRs of AER 12. The study revealed that the decadal growth rate in AESR 12.1 was 20% during 1981-91, whereas during 1991-2001 it was 4% lower. The population density was 160 and 182 during 1981-91 and 1991-2001, respectively, which was lower as compared to other AESRs. The literacy level was moderate in this sub-region, varying between 55 and 58% during the same period. In AESR 12.2, the population growth rate was 22 and 15% during 1981-91 and 1991-2001, respectively and the population density increased from 358 to 413 during this period. The literacy level was little higher in this sub-region (61 and 65% in 1981-91 and 1991-2001, respectively) as compared to other AESRs. In the AESR 12.3, decadal growth rate of population was 22 and 20% during 1981-91 and 1991-2001, respectively with population density of 410 and 494 during those respective decades. Highest population density (1167 per square kilometre) was found in Dhanbhad districts (AESR 12.3), which was predominantly an industrial hub.

Table 5.10: Inter-regional variation in population dynamics in AER 12

Particulars	Growth (%)		Density		Sex Ratio		Literacy (%)	
	1981-1991	1991-2001	1981-1991	1991-2001	1981-1991	1991-2001	1981-1991	1991-2001
AESR 12.1								
Mean	20	16	160	182	977	981	55	58
CV	15.0	25.0	58.8	54.9	2.3	2.0	32.7	20.7
AESR 12.2								
Mean	22	15	358	413	979	980	61	65
CV	22.7	26.7	28.5	29.8	2.6	3.0	29.5	18.5
AESR 12.3								
Mean	22	20	410	494	933	946	47	58
CV	18.2	25.0	51.2	51.8	4.3	3.2	25.5	19.0

Even though population growth is a very complex phenomenon guided by numerous direct and indirect factors, it was considered worthwhile to study its underlying dynamics. Considering the density, sex ratio and literacy as the major contributing forces for population growth multiple linear regression models were fitted in this study taking population growth as dependant variables with density, sex ratio and literacy as independent variable using the data of 1991-2001.

The statistical model taken for the study was:

$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + e.$

Where; $Y = \ln$ (growth %), $X_1 = \ln$ (density), $X_2 = \ln$ (sex ratio), and $X_3 = \ln$ (literacy), a = intercept, b_1, b_2, & b_3 = parameters and e = error-term which is distributed normally with mean zero and constant variance.

The results of analysis are presented in Table 5.11 which revealed that density contributed significantly to the population growth with 83% predictive power of model.

Table 5.11: Determinants of population growth in AER 12

Parameter	Co-efficient	Standard Error	't' statistics	Signi-ficance	R^2	F calculated
AESR 12.1						
a	65.50	24.90	2.60	0.03	0.83	13.30
b_1	-0.50	0.10	-5.80	Significant		
b_2	-8.50	3.50	-2.40	0.04		
b_3	-0.40	0.30	-1.30	0.20		
AESR 12.2						
a	-72.90	131.60	-0.60	0.70	0.73	0.90
b_1	-1.60	1.50	-1.10	0.50		
b_2	9.30	17.50	0.50	0.70		
b_3	5.10	4.10	1.20	0.40		
AESR 12.3						
a	26.90	26.90	0.90	0.40	0.29	1.10
b_1	0.20	0.20	0.20	0.80		
b_2	-3.70	3.70	-0.80	0.40		
b_3	-0.40	0.40	-1.50	0.20		

Consumption, nutrition and poverty

Access to food to provide nutrition security to the growing population is critical to maintain quality of life and progress of the society. But, larger proportion of population is either deprived of or not accessible to balanced food. Ultimately, food insecurity and nutritional insecurity persisted despite the growth and developments were achieved in agriculture in the past. For instance, UNICEF and World Bank's recent report says that 63% of children in India are malnourished and more than 50% are suffering from nutritional anaemia. Indian girls suffer from iron-deficiency linked anaemia and 50-90% of pregnant women suffer from energy deficiency of the order of 1000 kcal/day. In this study, consumption-driven calorie intake of rural and urban population of AER 12 is highlighted.

As the district-wise consumption data were not available, the state level data were taken for the study (based on NSSO survey). For estimating the consumption of major foodgrains by AESR, weighted averages were found out with proportion of district area of different states falling under an AESR as weighting factor. Again, major food items were considered which contributed about 75-80% of calorie requirement of the individual. Monthly per capita consumption of foodgrains for the states of AER 12 is given in Table 5.12. The per capita food and calorie consumption (80%) is given in Table 5.13.

Animal husbandry and fishery resources

The animal husbandry is emerging now as one of the important livelihood options among the landless and marginal farmers who do not get adequate livelihood support from crop husbandry. The

Table 5.12: Monthly average per capita consumption of foodgrains

Region	State	Rice (kg)	Wheat (kg)	Total cereals (kg)	Pulses (kg)	Monthly expenditure (Rs)
Rural	Orissa	14.2	0.6	15.1	0.5	373
	A.P.	11.7	0.2	12.7	0.8	453
	Bihar	7.9	5.3	13.8	0.8	385
	M.P.	5.5	6.6	12.9	0.9	401
	Maharashtra	3.2	3.5	11.3	1.0	497
	All India	6.8	4.6	12.7	0.9	486
Urban	Orissa	12.2	2.3	14.5	0.8	618
	A.P.	9.9	0.9	10.9	0.9	774
	Bihar	6.6	6.1	12.7	1.0	602
	M.P.	3.4	7.4	11.1	1.0	693
	Maharashtra	3.5	4.8	9.4	1.1	973
	All India	5.2	4.8	10.4	1.1	855

Table 5.13: Per capita consumption in AER 12

Items		Rural			Urban		
AESR		12.1	12.2	12.3	12.1	12.2	12.3
80% food consumption (kg/month)	Rice	11	12	10	10	12	8
	Wheat	2	0	6	3	2	4
	Cereals	14	14	14	13	14	12
	Pulses	1	1	1	1	1	1
80% calorie Consumption per day (kcal)	Rice	1521	1779	1313	1308	1422	987
	Wheat	204	46	809	403	178	626
	Cereals	1854	1773	1793	1721	1597	1592
	Pulses	78	90	90	104	105	109
	Total	1932	1862	1882	1825	1702	1701

eastern coastal districts under AESR 12.2 contribute maximum per capita availability per day of fish and meat, the values being 32.3 g and 29.0 g per capita per day, respectively (Table 5.14). This is the only sub-region of AER 12 where the per capita per day availability of fish is more than minimum required level (15 g) as well as average per capita availability in AER 12 as a whole (17.4 g). It was interesting to note that all the sub-regions of AER 12 consumed more than required amount of meat. Per capita per day fish availability in the AESR 12.2 also outweighed other AESRs as this sub-region is mostly coastal tract and is having maximum concentration of ponds and water bodies, fish availability is more in this sub-region. The traditional and commercial pisciculture economy could contribute significantly to the income of the people of the all the sub-regions. The per capita milk consumption per day was found higher in AESR 12.1 (132 g) followed by AESR 12.3 (93 g) and AESR 12.2 (78 g). The use of egg (number per capita per day) was almost comparable in all the AESRs.

Table 5.14: Per capita availability of major animal products in the region (g/day)

AESRs	Milk	Egg*	Meat	Fish
12.1	132	0.069	21.0	12.5
12.2	78	0.075	29.0	32.3
12.3	93	0.089	21.4	7.4
AER 12	100.8	0.077	23.8	17.4

Note: Computed from Dairy India, 1997 and Statistical Abstract of India, 2000.
* Egg is in no. per day

Major livestock population

Among different major livestock population, buffalos were noted more in AESR 12.1 (48.2%) as compared to those in other sub-regions (Table 5.15). The cows are more (53.4% of total of AER 12) in AESR 12.2. The sheep and goat population (40.3% and 48.8% of total in AER 12, respectively) was also the highest in AESR 12.3. This region is predominately inhabited by tribal population who traditionally rear poultry and small ruminants.

The production of fish was recorded highest in AER 12.2 (50499 tonnes) with per capita per day availability of fish at 32.3 g (Table 5.16).

Table 5.15: Major livestock population in AER 12

('000)

Region	Buffalo		Cow		Sheep		Goat	
	No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent
AESR 12.1	138	48.2	447	31.9	114	25.6	364	23.7
AESR 12.2	104	36.5	834	53.4	152	34.1	425	27.7
AESR 12.3	44	15.3	231	14.8	180	40.3	748	48.8
AER 12	286	100	1562	100	446	100	1537	100

Note:Computed from Reports on Livestock Census, 1995, different State Governments.

Table 5.16: Fish availability in AER 12

AESRs	Production of fish (tonnes)	Per capita availability of fish (g)
AESR 12.1	9484	12.5
AESR 12.2	50499	32.3
AESR 12.3	5355	7.4

Source: Reports on Livestock Census, 1995, different State Governments

Summing up

Production planning related issues

As far as resource potentials are concerned the AER 12 is well endowed with climatic and other natural resources. The utilization of these resources to the advantage of the growing population has been remained sub-optimal over the years and the region continues to suffer from acute poverty, malnutrition, low agricultural production and productivity. The policy planning for development of resources should be based upon internalising capacity of empowered human resource that is central to development.

Emphasis on farming system approach

Crop husbandry alone is inadequate to support the livelihoods of the people. Fisheries and livestock as alternative sources of income available to the people are yet to be explored economically. Tribal population in the region constitutes 40% of total population with low level of literacy, high infant mortality rate, low level of crop and animal husbandry productivity. Enhancement of income through adoption of farming system approach is the need of the hour to improve overall productivity of the region.

Water Resources

Groundwater development

The groundwater resource status of AER 12 varies widely due to hydro-geological situations of different aquifers and their water bearing strata. Groundwater development is quantified as net annual draft, expressed as a per cent of utilizable groundwater resources for irrigation at five yearly intervals. Based on the status of groundwater development, areas were categorized into four classes namely white, grey, dark and over-exploited blocks with groundwater development status at < 65%, 65-85%, 85-100% and > 100%, respectively. The groundwater status in different AESRs is discussed below

AESR 12.1

On the basis of groundwater assessment and its draft for irrigation, domestic, industries and other uses, its development is very low in AESR 12.1 (7.3-13.7% in the state of Orissa, 1.1% in Bastar district of Chhattisgarh, and 13.3% in East Godavari of Andhra Pradesh and 7 and 16% in Chandrapur and Gadchirolli districts of Maharastra). Since groundwater development of this region falls under white area category, substantial scope for exploitation of groundwater exists in the region. Financial help from the government institutions in terms of providing deep tube wells/open wells on community ownership basis are the real need so that marginal farmers can use groundwater for irrigation during *rabi* and summer seasons. The mean total replenishable groundwater resources (TRGWR) of this region were found 287001 ha-m with utilizable groundwater resources for irrigation (UGWRI) 244804 ha-m (Table 5.17).

Table 5.17: Groundwater status in AER 12

(ha-m)

Particulars	TRGWR	PDI	UGWR	Net draft	Balance	IP	GWD (%)
AESR 12.1							
Mean	287001	34034	244804	26606	251065	168702	11.4
CV(%)	42.8	63	39.2	19.6	42.4	163	40.4
AESR 12.2							
Mean	164340	12018	202737	24941	121157	105039	12.7
CV(%)	68.3	22.9	35.6	80.7	64.1	44.6	28.7
AESR 12.3							
Mean	72579	5557	39689	12422	80143	61379	10.6
CV(%)	75	41	88	281	37	5	119

TRGWR = Total replenishable groundwater resources
PDI = Provision for domestic and industrial use
UGWRI = Utilizable groundwater resources for irrigation
UIP = Utilizable irrigation potential for development
GWD = Groundwater development
IP = Irrigation Potential

AESR 12.2

In AESR 12.2, though the groundwater development was found comparatively higher than in other sub-regions, substantial scope for groundwater exploitation still existed in this zone. Since rainfall received in this AESR was quite sufficient (1200 and 1700 mm), the irrigation requirements of the crops were being meet through rainwater stored in different irrigation projects. However, further groundwater development is needed for increasing the cropping intensity beyond the current level of 134% in this sub-region. The TRGWR of this sub-region was 164340 ha-m with UGWRI being 202737 ha-m.

AESR 12.3

In AESR 12.3, groundwater development was noticed quite low. It was because of very low groundwater development in 8 districts of Jharkhand, which ranged from 1.5 to 11.6%. In Keonjhar district of Orissa under this sub-region, groundwater development was 12.1%. Major parts of this district are underlying by hard crystalline rocks and groundwater development is feasible through dug wells in hard rock areas and through dug wells, filter point and shallow tube wells in the alluvium zone. Under this sub-region in West Bengal, groundwater development was maximum (48.3% in Midnapur West and in rest of the four districts it ranged from 10.5 to 18%). The mean TRGWR of the sub-region was 72579 ha-m with groundwater development of only 10.6% and UGWRI of 39689 ha-m.

Groundwater quality

AESR 12.1

The groundwater quality in shallow wells has a marked difference in rock and coastal areas. More than 50% of total studied samples were of Ca-Mg-HCO_3 type. Mixed type of water was available, especially in districts of Koraput, Kalahandi and Sundergarh in the sub-region. High electrical conductivity (EC) values (above 1000 μS/cm) were observed in Kalahandi district (AESR 12.1) and in western part of Koraput. Sulphate in the groundwater was not a problem and was found mostly below 25 mg/l. In the hard rock area, high sulphate content was observed in the western part of Koraput, Kalahandi and Dhenkanal districts. Incidence of high fluoride in groundwater was found in some cases. The values were generally below 1.0 mg/l. In Phulbani district, where groundwater occured in hard rocks, some of the well waters were having high fluoride (3.3 mg/l), which could be due to occurrence of fluorine-bearing minerals.

High values of nitrate, which were desirable for infant health, had also been found in the area. Maximum permissible limit is 45 mg/l. Nitrate values above 100 mg/l were found at Saintala Public Works Department (PWD), I.B (232 mg/l) in Bolangir district and at Padmapur (113 mg/l) in Sambalpur district. The high nitrate content could be due to human activities and use of fertilizers.

High values of nitrate along with potassium and sulphate were found in Ganjam district, which was due to use of fertilizers. Iron in the groundwater of Orissa was generally below 0.3 mg/l, which is a limit from aesthetic point of view. High values of iron were found at Kodinga (4.1 mg/l) and Parhaia (3.4 mg/l) villages in Koraput, at Rutra (8.7 mg/l) village in Sambalpur district.

AESR 12.2

In the coastal area, the highest value was observed at Bari in Cuttack (7.2 mg/l), which might be due to dissolution in the catchments area from hard rocks. High content of fluoride in drinking water is injurious to health, while low values also interfere with the normal growth of teeth. In coastal area of AESR 12.2, high values of chloride existed due to seawater ingress.

In the coastal tract of this sub-region, most of the groundwater was of $NaHCO_3$ or NaCl type, which might be due to base-exchange process and due to proximity of the sea. The electrical conductivity (EC) was generally below 750 µS/cm at 25^{0}C. The low values of EC were found in the hard rock areas, which formed the catchments of the river basins. Out of the four districts lying in the coastal area, groundwater in Balasore and parts of Puri was having EC of more than 1000 µS/cm in most of the wells. In coastal Orissa, high values of sulphate were observed in some cases, which could be due to proximity to the sea, e.g. Ananthpur (390 mg/l) and Motto (345 mg/l) in Balasore district.

In general, groundwater from coastal areas have more iron than the hard rock areas. Groundwater is suitable for drinking purposes except in cases where high values of iron, nitrate and fluoride are found. Suitable treatment is required for removal of high iron and fluoride and preventive measures are required for high nitrate-content. Groundwater is also suitable for irrigation purposes except in few pockets of coastal area where highly saline water is available.

AESR 12.3

The electrical conductivity (EC) of the collected water samples of four districts of AESR 12.3 (Bankura, Birbhum, Midanapore and Purulia) were within the permissible limits both for irrigation and domestic uses and these ranged between 462.61 µS /cm and 872.55 µS/cm at 25^{0}C. In the eastern part of Midnapur, EC of groundwater from deeper aquifers was found up to 1575 µS /cm at 25^{0}C and chloride content of 337 mg/1 which was quite harmful to human health, if used for drinking purpose. The fluoride concentration was within maximum permissible limits (1.5 mg/l), except in few areas, namely Raipur in Bankura district (82 mg/l).

Groundwater table

AESR 12.1

Based on water level monitoring during pre-monsoon, peak monsoon, post-monsoon and recession stage of water levels, it was revealed that depth to water level ranged from 1.9 to 9.8 mbgl (metre below ground level) in pre-monsoon period and at surface to 7.3 mbgl in peak monsoon period (August 2000 data). During post-monsoon (November 2000), and during recession stage (January 2001), groundwater level increased from 1.5 to 10.6 mbgl. In this sub-region minimum groundwater table (average of different districts) was found at 3.9 mbgl and maximum, at 9.8 mbgl during April, 1998. While during November 1988 minimum was at 1.1 mgbl and maximum, at 9.1 mgbl (Table 5.18).

Table 5.18: Groundwater level in AER 12

AESR	Range of depth to water level (mbgl)			
	April 1988		November 1988	
	Min.	Max.	Min.	Max.
12.1	3.9	9.8	1.1	9.1
12.2	1.2	11.4	2.8	6.8
12.3 (Keonjhar)	1.9	13.1	9.6	9.6

Source: Hydrogeological Atlas of Orissa, Central Groundwater Board, Regional Office, Bhubaneswar, 1995.

AESR 12.2

In post-monsoon period, the minimum depth to water table was observed in the coastal tract of Puri district, parts of Ganjam, Balasore and Cuttack. In other parts of coastal tract, these values ranged from 2 to 4 mbgl. In case of confined zone in the coastal tract, the piezometric head rested in summer from 0.6 to 10.8 m and in post-monsoon period from 0.4 to 5.4 m below land surface. In the case of deeper fractured zones in hard rocks of Kalahandi district, the static water level varied from 4.2 to 19.7 m below land surface during pre-monsoon period. The average minimum depth of groundwater was 1.2 m and maximum was 11.4 m during April, 1988, while in November 1998, minimum water depth at 2.8 m and maximum was at 9.6 m depth in this sub-region.

AESR 12.3

In AESR 12.3, the groundwater fluctuation data showed that in the month of April 1998, groundwater level was minimum at 1.3 to 2.4 metre mbgl and maximum at 10 to 20 mbgl in four districts of West Bengal. The groundwater table at greater than 20 m depth was recorded during August 1998 in only one observation well in Bankura district. In rest of the districts, the groundwater level was fluctuating up to 20 m depth. In Purulia district, groundwater level was at shallow depth. During rainy and post-rainy seasons in Purulia district, the groundwater level came to the surface, i.e. 0.09 mbgl. When groundwater level was categorized among observation wells/ piezometers, the maximum number of observation wells showed water table within 2-5 metre depth in almost all districts. Such shallow groundwater levels can be effectively utilized for irrigation purpose, as pumping cost will be less. So these observations are very useful for irrigation development of district as a whole. In Keojhar district of Orissa minimum water depth was at 1.9 mbgl and maximum at 13.1 mbgl.

Irrigation Status of Major Districts in AER 12

The source-wise irrigation (2000-2001) in districts of Orissa under AER 12 is presented in Table 5.19. The study reveal that in AESR 12.1 the highest irrigated area was due to major and medium projects with the highest area at Sambalpur (216.9 thousand hectares) whereas in AESR 12.2, Cuttack was having the highest irrigated area (386.6 thousand hectares) by major and medium projects. Among different AESRs of Orissa, the total irrigated area from all sources was the highest at Cuttack (552.6 thousand hectares) followed by Puri (337.6 thousand hectares).

Waterlogging

Canal irrigation creates waterlogging conditions in pockets particularly in Mahanadi delta I, delta II and in Hirakud commands because of poor drainage and shallow water table. This necessitates good drainage measures in canal-irrigated areas and also conjunctive utilization of surface and groundwater. The waterlogged areas in different districts of Orissa under AESR 12.1, 12.2 and 12.3 are given in Table 5.20.

Table 5.19: Source-wise net irrigated area

('000 ha)

Name of the districts (undivided)	Major and medium	Minor (flow)	Minor (lift)	Total from all sources
AESR 12.1				
Bolangir	87.6	25.7	23.9	137.2
Dhenkanal	39.6	45.2	30.1	114.9
Kalahandi	134.5	32.2	22.7	189.4
Koraput	166.3	41.6	48.7	256.6
Mayurbhanj	52.0	39.4	24.8	116.2
Phulbani	25.5	22.1	13.3	60.9
Sambalpur	216.9	44.9	25.6	287.4
Sundargarh	20.9	32.8	19.00	72.7
AESR 12.2				
Cuttack	386.6	27.2	138.8	552.6
Puri	259.8	39.2	38.6	337.6
Ganjam	131.7	127.4	44.9	304.0
Balasore	119.9	11.6	82.4	213.9
AESR 12.3				
Keonjhar	34.4	31.0	24.7	90.1
Total	1675.7	520.4	537.5	2733.6

Source: Orissa Agriculture Statistics, 2000-01

Physiography and drainage of AER 12

In Orissa the plateaus form a flat upland terrain covering parts of the districts of Mayurbhanj, Keonjhar, Sundergarh and Western Koraput and Kalahandi. The general elevations ranges from 500 to 600 m above MSL. The long chain of hills in the mountainous southern Orissa forms parts of the Eastern Ghats ranges extending over a distance of about

250 km in the districts of Koraput, Kalahandi, Phulbani and Ganjam. It forms the watershed of the Rushikulya, the Vamsadhara and the Nagavalli rivers. The altitude of the terrain ranges from 600 to 1200 m above MSL. The prominent peaks are the Deomali (1673 m) and the Tusiakonda (1599 m) in Koraput district and the Mahendragiri (1531 m) in Ganjam district. The rolling uplands have a moderate height between 150 and 305 m and covers parts of Bolangir, Sundergarh, Sambalpur, Kalahandi, Dhenkanal, Ganjam, and Phubani districts. The

Table 5.20: Waterlogged areas

('000 ha)

Districts	Irrigated area by major and medium projects (up to 1989)	Area in '000 ha	Percentage of water-logged with respect to irrigated area
AESR 12.1			
Bolangir	52.4	3.4	6.4
Sundargarh	9.9	1.8	18.3
Dhenkanal	21.3	0.9	4.1
Sambalpur	121.6	7.7	6.1
Kalahandi	18.1	6.3	3.5
Koraput	43.9	3.8	8.7
Mayurbhanj	32.9	1.2	3.7
Phulbani	22.3	1.1	5.0
AESR 12.2			
Puri	181.6	13.9	7.7
Ganjam	102.5	5.7	5.8
Balasore	87.7	6.4	7.3
Cuttack	204.8	21.4	10.4
AESR12.3			
Keonjhar	26.4	0.9	3.7

Source: Orissa Remote Sensing Application Centre 1995.

river valleys and plains are drained by the Mahanadi, the Brahmani, the Rushikulya, the Vamsadhara, and the Telmand (altitude varies from 75 to 150 m above MSL).

The coastal plains form an extensive alluvial tract stretching from the Subarnarekha in the north to the Rushikulya in the south. It forms parts of the deltaic tract of the Mahanadi, the Brahmani and the Baitarani rivers in the district of Balasore, Cuttack and Puri. It can be divided into three units, viz. (i) narrow saline marshy tract, (ii) intermediary belt, and (iii) crescent-shaped upland region. The narrow saline marshy tract runs parallel to the coast with an average width of 3 to 10 km. It has a low relief with general altitude of 1.5 m above MSL. The intermediary belt is having a width of 16 to 72 km and the general slope is towards east and south-east. The crescent-shaped upland region consists of lateritic hillocks adjacent to Eastern Ghat hill ranges. The Mahanadi, the Brahmani, the Baitarani, the

Burhabalang, the Subarnarekha, the Rushikulya, the Nagavalli and the Vamsadhara and their tributaries form the drainage system in the state.

These rivers are perennial maintaining a sluggish flow in the pre-monsoon period but swelling menacingly with the onset of monsoon, often flooding large tracts. The important stream gauging stations operated by Central Water Commission and State Government and the discharge of water through rivers in parts of Orissa under AER 12, are given in Table 5.21. The Chilka lake is another prominent physiographic feature in AER 12.1, which is a lagoon (75 km long and 32 km wide), isolated from the sea by sand bars.

Table 5.21: Drainage areas of the major rivers within Orissa

Name of river	Drainage area (sq km)	Annual flow (MCM)
Mahanadi	65,579	51,061
Brahmani	22,248	18,311
Baitarani	12,789	5,452
Subarnarekha	2,123	7,941
Rushikulya	4,847	637
Vamsadhara	7,753	1,762
Nagavalli	8,015	3,460
Indravati	3,746	2,430
Kolab	7,512	2.8
Machhakund	7,639	2,615

Source: Irrigation Department, Government of Orissa, 1988.

In the parts of Madhya Pradesh under AER 12 the main physiographic unit is Bastar plateau in southern part of the region. The Baster plateau, covering the district of Baster, Kanker and Dantewada represents the third physiographic unit in southern part of state, which is unique for its predominant forestland. Except plains of Kanker, and Jagdalpur area, most of the area is covered with evergreen forest and hilly tract, the altitude of which varies from 400 to 600 m above MSL. In plain area, along Indravati river, in central part and along the Sabari river, in the south-east, the altitude ranges from 250-300 m above MSL. In this plateau region, the major rivers that are draining the state of Chhattisgarh are the Mahanadi, the Indravati, the Sone and the Narmada. Most of the rivers are perennial and effluent in nature. The predominant drainage patterns are dendrite, parallel, angular and radial types. The salient features of the major river basins and water availability in Chhatisgarh (AESR 12.1) are given in the Tables 5.22 and 5.23.

Table 5.22: Major river basins in Baster plateau

Major rivers	Tributaries	Districts drained by the river
Mahanadi	Ib,Hasdeo,Seonath Telmand	Raipur, Mahasamund, parts of Durg, Rajnandgaon, Kaward, Kanker, Baster, Surguga, Raigarh, and Bilaspur
Godavari	Sabari, Indravati	Parts of Raipur, Baster, Rajnandgaon, Kankar and Dantewada.

Source: Groundwater Yearbook 2000-2001, CGWB, North Central Chhattisgarh Region, Raipur.

Table 5.23: River basin and water availability in Chattisgarh part of AESR 12.1

Name of river	Basin area (sq km)	Percentage of Basin area over geographical area of district	Length of river (km)	Water available (MCM)
Indravati	26,620	67.8	372	12,710
Sabri	5,680	14.5	180	2,632
Godavari	4,240	10.8	24	1,997
Mahanadi	2,640	6.9	64	1,026

Source: Groundwater Yearbook 2000-2001, CGWB, North Central Chhattisgarh Region, Raipur.

Under AER 12 in Maharastra, two areas were identified based on physiographic situation:

(i) The plain and fertile region, lying in the river valley of the Wardha, Penganga and Wainganga rivers. The widely spread flat terrain generally occurs along the Wardha river. In Wainganga valley, the flat terrain exhibits mostly the rolling topography in the southern portion while in the northern portion of the river it is alluvial with fertile lands. In Paiganga valley flat terrain covers very little area in the south-western portion of the district.

(ii) The upland hilly region lying between Wardha and Wainganga rivers. It has sandy soil. The area occupied by Penganga basin in the south/western part of the district with ostly hilly topography of the district. The entire area falls under the Godavari basin. The area is drained by major tributaries, viz. Wardha, Wainganga and Penganga of the Godavari river. The Penganga, flowing along the western boundary meets the Wardha river. It further flows in north-west and south-east direction and finally merges into the Wainganga river at the south-eastern corner of the Chandrapur district of Maharastra.

Summing up

Groundwater development planning

There is enough scope for groundwater development in the region for which both State and Central Governments have to develop infrastructural facilities and farmers have to use and maintain borewells/tubewells on community participation basis. In low water bearing strata, development of rainwater harvesting structures is required to allow maximum rainwater conservation in small ponds, which will recharge groundwater and may be utilised during *rabi*/ summer season. Regarding quality of groundwater, it is suitable for both domestic and irrigation, except in the coastal area of Orissa and Andhra Pradesh, where the under ground deep water is saline and shallow water is marginally good.

Groundwater table

Regarding groundwater table, in most of the hydrographs, groundwater level during south-west monsoon and post-monsoon seasons is at shallow depth. During post-monsoon period, the fluctuation of groundwater level is within 5-10 metre. This water depth is also feasible to exploit well water by pumping during summer season where high value cash crops are grown. However, the water discharge rate should be sufficient to irrigate maximum area.

Conjunctive use of water

High rate of seepage water is leading to situations of perched water table at many locations that prohibits the adoption of crops other than rice in such areas even in the summer season. Conjunctive use of groundwater and surface water is needed to reduce the level of water table in the command areas.

Agro-economic characteristics

The agro-economic characteristics of the region are predominantly subsistence in nature and are beset with low productivity, low level of input use, low capital formation, low income and consequent poverty. The predominant agriculture is rice-based which is characterised by low input use, low mechanisation and low productivity, resulting in low income to the farmers.

Distribution of land holdings

The distribution of farmers of the region according to size of operational holdings revealed that about 57.9% farmers, owning 21.4% of total operational area were marginal farmers whereas only 0.5% farmers were large farmers with 24.8% of total operational area of the region. In other words, the proportion of marginal holdings to total landholdings was sufficiently large compared to other categories of land holdings. It was also noted that the proportion of marginal farmers was the highest in AESR 12.2 and the lowest was in AESR 12.1. The nature of distribution of land holdings across the sub-regions is shown in Table 5.24.

Table 5.24: Distribution of landholdings and area operated in AER 12

(%)

AESRs	Below 1 ha.		1-2 ha		2-4 ha		4-10 ha		> 10 ha	
	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
12.1	46.8	16.7	26.3	24.7	17.9	29.5	7.6	23.8	0.9	6.7
12.2	66.2	27.8	20.4	26.3	10.2	27.8	2.8	15.1	0.2	4.2
12.3	60.6	20.7	21.2	23.4	12.9	28.4	4.7	21.6	0.4	5.9
AER 12	57. 9	21.4	22.6	24.8	13.7	28.6	5.0	20.2	0.5	5.6

Note : Computed from Reports on Agricultural Census, 1995-96, Agriculture Department of different State Governments

In the AESR 12.1, the proportion of marginal farmers (with operational area below 1 ha each) was 46.8% with 16.7% of total operational area where as 0.9% farmers in the large farmer category (with more than 10 ha of operational area each) occupied 6.7% of total operational area. This depicted the existing level of inequality in distribution of land resources in the sub-region. It was noticed that this type of inequality level was maximum in AESR 12.2 and the lowest in AESR 12.1. About 66.2% of total farmers in the AESR 12.2 were marginal farmers with just 27.8% of total operational area and the large farmers constituting 0.2% (which was the lowest of all the sub-regions of AER 12) of all categories of farmers occupied 4.2% of total operational area.

Agricultural production scenario in AER 12

The production of food grain was found more in AESR 12.1 with maximum area under cereals in comparison to other sub-regions (Table 5.25). The AESR 12.1 also over-scored other sub-regions in terms of production and area under oilseeds. However the fertiliser consumption was more under AESR 12.2 (mostly coastal tracts). In AESR 12.3, production of food was less as compared to that in other sub-regions of AER 12.

Table 5.25: Area and production of foodgrains in AER 12

AESRs	Total foodgrain production ('000 tonnes)	Average fertilizer consumption (kg/ha)	Net cultivated area ('000ha)	Total area under ('000ha)		
				Cereals	Pulses	Oilseeds
12.1	535.4	34.3	252.7	345.3	104.6	74.2
12.2	388.4	57.4	238.1	342.5	126.2	60.5
12.3	136.3	49.3	156.0	236.0	66.0	45.0

Source: Various Publication of Directorate of Economics and Statistics, Respective State Governments, 1999-2000

Rice is the predominant *kharif* crop occupying 70-90% of the entire region under irrigated and rainfed conditions. At some places pulses and oilseeds are also grown as rainfed *kharif* crops but productivity is very less(2-3 q/ha). Wheat, potato, sugarcane, pulses and oilseeds are the major r*abi* crops while jute is also grown as pre-monsoon crop in some areas. The detailed AESR-wise existing crops and cropping sequences are presented in Table 5.26.

Existing crops and crop sequence

Under AER 12, rice is most dominant crop during k*harif* in all AESRs. However, in *rabi* season type of crops varies in different AESRs. Some of the major rainfed and irrigated cropping systems are discussed below.

Table 5.26: Existing cropping pattern and crop sequences in AER 12

AESR	Crops	Cropping system
12.1	*Kharif* Rice, seasmum, finger millet, cotton, groundnut, sugarcane, horsegram, maize *Rabi* Potato, groundnut, vegetables, sugarcane	(i) Rice/Cotton/Groundnut/ Maize/ Pulses (rainfed upland) (ii) Rice-pulse (rainfed low land) (iii) Millet (kharif)-maize (rabi)/ maize (kharif)-mustard (rabi) (iv) Rice-groundnut/vegetable / sugarcane/rice (irrigated) (iv) Rice (rainfed)-wheat/potato (irrigated)
12.2	*Kharif*: Rice, jowar, groundnut, maize (upland) *Rabi*: Rice, pulses, vegetables, sugarcane, wheat	(i) Rice- pulse (rainfed) (ii) Rice-sunflower (irrigated) (ii) Rice-groundnut (rainfed/ irrigated) (iii) Rice (rainfed)-rice/wheat/ vegetables /potato (irrigated) (iv) Horticulture (sloppy land)
12.3	*Kharif*: Rice, maize, ragi, pigeonpea, *Rabi*: Wheat, vegetables, potato	(i) Rice -fallow (ii) Rice (rainfed) /wheat/potato/ vegetables (irrigated) (iii) Millets / Jute (rainfed uplands)

Source: Report on Quinquennial Review Team, WTCER, 2001

Irrigated cropping pattern

(i) Rice-rice cropping system

In the irrigated tract of the AER 12 such as coastal areas of Orissa and Andhra Pradesh, the widely adopted cropping pattern was rice-rice. This was also observed in the inland districts and plateaus of this region. Under the irrigated conditions, rice was being cultivated by transplanting method. For sowing in nursery, raised beds are prepared. The usual practice of water management in the canal command areas is continuous ponding and field-to-field irrigation. The constraints of deterioration in soil physical conditions due to repetitive puddling, emergence of micro-secondary nutrient deficiencies and poor nitrogen-use efficiencies with unbalanced fertilizer-use were observed in this type of cropping system. The rise in water table, deteriorating soil health condition due to waterlogging and secondary salinization were some of the emergent issues under irrigated cropping system in this region. Prevalence of imperfect drainage and non-judicious use of water had resulted in multifarious water-related problems. The field-to-field irrigation practice and raising rice under continuous ponding system were found in vogue in the coastal irrigated tracts and inland districts of Orissa and plateau of Jharkhand. The use of advanced system of irrigation like pressurized irrigation for low duty cash crops, mulching and proper irrigation scheduling are advocated for water saving. Judicious and integrated use of inputs on the line of scientific prescriptions is advocated for emphasis in extension endeavour in the region.

(ii) Rice-groundnut cropping system

After kharif rice, *rabi* and summer groundnut were found becoming popular for irrigated farming in the region. Area under summer groundnut in irrigated condition was increasing in these areas. The edaphic condition in *rabi* was more favourable to grow groundnut on well drained and fertile lands as an alternative to rice crop. However, the field-to-field irrigation practice by rice growing farmers in *rabi*/summer often restricted the scope for area expansion under groundnut or any other water-sensitive non-rice crops and crop diversification.

Rainfed cropping pattern

The cropping pattern in rainfed condition was found mostly rice-fallow in major tracts of the region. The picture of mixed farming was prevalent that combined crop husbandry with animal husbandry and other livestock rearing. Intercropping and *paira* cropping* were the emerging trends in the region in all land types. Rice was mostly grown as staple crop; other crops includes finger millet, niger, horsegram etc. in upland conditions. In plains, a second crop of mustard or cowpea was common practice under rainfed condition. Vegetable through protective irrigation was also grown in the region. Turmeric and ginger were also common crops in rainfed uplands during *kharif* season. In rainfed low lands, rice-pea or rice-gram was followed in limited areas. Broadcasting of dry seed of upland crops was the most common practise in all the landforms of the region during *kharif* with very minimal fertilizer application. The low land, transplanted rice was the most important crop for the farmers in rainfed

* *Paira* cropping is practised in some parts of the region where immediately after or one week before the harvest of rice, the seeds of short duration legumes are broadcasted into the moist soil.

areas. Nurseries are raised for transplanting in low lands and some of the medium lands. Bushening is practised in uplands for weed suppression. The practice of a second crop in uplands is rare due to delayed sowing, however if early sowing was taken up, a second crop could easily be raised under extended rains and extended soil moisture availability as was proved under NATP programmes in plateau districts of the region.

Constraints to rice production in rainfed uplands under AER 12

The soil moisture stress, continuous loss of soil fertility, accumulation of toxic decomposition products, imbalanced use of fertilizer in uplands, poor drainage, low-lying physiography and high rainfall in submergence-prone lowlands, continuous use of traditional varieties of seeds, heavy infestation of weeds and insect pests, poor crop stand establishment and poor adoption of improved crop production technologies were some of the major constraints for rice cultivation in the rainfed area of AER 12.

Moisture stress was specifically due to erratic and skewed rainfall, high run-off, poor soils, and lack of facilities for rainwater and soil moisture conservation/life-saving irrigation in upland and drought-prone rainfed lowlands of different sub-regions of AER 12.

Intermittent moisture stress was due to low and erratic rainfall, and poor soils as in Chattisgarh, Orissa and Jharkhand. Low soil fertility was due to soil erosion leading to loss of soil nutrients and moisture. Accumulation of toxic decomposition products in ill-drained soils and soil reduction was encouraging the problems of iron toxicity, as in coastal parts of Orissa. Non-availability of any suitable method to apply the fertilizer in standing water in rainfed lowlands and semi-deep and deepwater areas has lead to low and imbalanced use of fertilizers in the uplands (20-40 kg $ha^{-1)}$. Flash floods, waterlogging/submergence were due to the poor drainage, low-lying physiography and high rainfall in submergence-prone lowlands, as in coastal Orissa and coastal Andhra Pradesh.

The continuous use of traditional varieties was found due to the non-availability of improved seeds and farmers' lack of awareness about application of HYV seeds in uplands, rainfed lowlands and deepwater areas of the region. Poor adoption of improved crop production technologies was basically due to technology inappropriateness and economic backwardness of farmers in uplands and lowlands of the region.

Heavy infestation of weeds and insect pests such as blast and brown spot and poor attention for their timely control was also a matter of concern in the uplands and rainfed lowlands.

Poor crop stand establishment due to broadcast seeding resulting in uneven germination in uplands and direct-seeded lowlands; delay in monsoon onset, often leading to delay and prolonged transplanting and sub-optimum plant population mostly in rainfed lowlands reduced the rice yield substantially.

SWOT analysis of rainfed rice production system

The SWOT analysis of rainfed rice-based cropping system has been discussed by Singh (1992) based on pilot survey under sustainable rainfed and development projects as follows.

Strengths

Rice will continue to be a staple crop for the region and is perceived as prestigious crop. It is also grown in all types of land forms and is tolerant to waterlogging and salinity.

Weaknesses

The spread of HYV is slow in rainfed tribal districts due to cultural preferences of the people and low level of income that prevents timely input application. Extension is week in these areas

Opportunities

Under proper management, the adoption level may go up and possibility of fodder cultivation is high under intensive extension. If improved farming system is extended the HYV adoption would improve. Second crop under early sowing is distinctly possible under improved soil moisture condition

Threats

Eroding soil condition, rainfall variability and low level of economic condition of farmers may impede the rainfed productivity in the region.

Realities in rainfed rice farming

- Population growth at the present rate of 2.1% per annum will continuously require more food. Yield stagnation in irrigated areas has necessitated turning the focus to the rainfed rice ecology.
- Improved rice production and productivity in this region may not only help the resource-poor farmers of the region but may also substantially increase the food production of the nation.
- Improved rice production technology, along with a limited number of suitable high-yielding varieties (HYVs) of rice, now available for each of these unfavourable ecologies, needs proper exploitation.
- With national and international collaborative efforts, it has now become possible to develop better location-specific technology and HYVs having regional adaptability at a faster rate through the consortium approach.
- A modest increase by half a tonne per hectare in rice yield in the rain fed ecosystem can add about 10 million tonnes of extra rice from the eastern India itself to meet the target of rice production of the country in the next five years.
- Extension agencies have to play a major role to educate the farmers about recent developments. Farmers' participation in the process of refinement and acceptance of modern production technology has begun to make an impact and merits wider application of this approach in other research and development programs.

Intercropping

A number of crops are grown in intercropping system that includes pigeon pea, cowpea, black gram, groundnut, etc. in upland situations. The results of these combinations have shown rice and pigeon pea to be the most promising intercrop combinations for plateau region of Bihar, while rice and groundnut intercropping is the most promising for Orissa.

Irrigated cropping system in AESR 12.1 (Hirakud Command) – A case study

The Hirakud Dam Project is one of the major multi-purpose river valley projects constructed in India after attaining independence. The Dam on the Mahanadi River is 4800 m long with catchment area of 748 square kilometres. The gross area irrigated by the project is about 1.55 lakh hectares and 1.08 lakh hectares of land during *kharif* and *rabi* respectively with 170% cropping intensity. It is seen that during *kharif,* almost whole command (98%) is under paddy as against the planned area of 70%. The deviation in paddy area during *rabi* is almost double the planned acreage. Based on this and subsequent studies undertaken by Chiplima Centre rice-groundnut appears to be the most economically viable double cropping system and rice-mustard-groundnut as the triple cropping sequence for this command.

Recommended cropping sequence based on water requirement:

To increase irrigation productivity, it is necessary to select a cropping system requiring less irrigation water so that net return per unit water resource is increased. The water requirement for rice-rice system is about 2450 mm in case of Hirakud command that is much higher than the water requirement for other types of cropping sequence. It is advocated that rice-rice system may be practised in head reaches of the canal commands. In the middle reaches and under conditions of lesser water availability, rice-pulse and rice-wheat and rice-vegetable system is feasible. In the extreme conditions of water scarcity, the sequence should be low water consuming ones like groundnut or maize followed by *rabi* pulse crop.

Water balance at the distributary level

The Chiplima Centre in Sambalpur district under AESR 12.1 has estimated an amount of 248 MCM as crop water demand in the command area of the distributary. As against this, the total water supply including rainfall was estimated to be 258 MCM resulting in an excess of 10 MCM. Groundwater availability of the command area (12690 ha) was 12690 ha m. But the annual draft was only 162 ha-m (1.3%). Thus, there is considerable excess water available at the head reach of the system, which can be utilized at mid-reach and tail-end for increasing the command area under gravity flow. Excess water at head reach can also be utilized for development of canal lift irrigation with crop diversification, thereby increasing the cropping intensity. It was also assessed that there had been gradual rise in water table after introduction of irrigation in the region.

Improved technology application at farmer's fields

The Chiplima Centre reported that rice-potato sequence was the most remunerative crop sequence, giving optimum monetary return of Rs. 25185 per ha which was 35 per cent higher over farmers' sequence of rice–mustard–rice. At Bilaspur, improved water management practice produced yields of 4.6 t/ha and 4.7 t/ha of summer and *kharif* rice, respectively, which were 27 and 23 per cent higher over farmers' traditional practice of sowing with 20 per cent irrigation water.

Major constraints in canal dependent cropping system

Different studies pointed out that high variability and undependable canal release pattern adversely affect the introduction of scientific cropping systems in the command areas. Canal outlets do not provide any control of the flow to the watercourses. Number of unauthorized outlets is more than the authorized outlets. Both the situations lead to inequitable water distribution and management. Variability in water release is common among different reaches of the canal system. The flow in the canal distribution system is frequently impeded due to weed growth and heavy siltation. There are also instances of obstructing canal water through creating artificial cross bunds by farmers to facilitate the flow into unauthorized outlets as well as for fishing. There is no effective control over water delivery by the irrigation authorities. It was observed that supply led over irrigation at head reaches and over-utilization of irrigation water by some influential farmers at middle/tail reaches were common practices in command area for most of the crops, which is leading to unfavourable soil moisture regimes and leaching of fertilizers. This has resulted in sub-optimal use of other inputs.

Accumulation of rainfall and lateral flow due to impervious layers was observed in the command area at its lower reaches. This affected the productivity of the crop adversely. There were instances where the once high producing low land areas had become low productivity areas due to water stagnation after the introduction of irrigation. Even though an effort has been initiated, farmers' participation in irrigation system management at the outlet level, no effective results have been observed in most of the areas.

Yield of major crops

A study of the crop yield of major crops across the sub-regions revealed that AESR 12.3 had performed better than other sub-regions in terms of productivity of rice, wheat, green gram, sesamum, mustard, sugarcane and potato, while the productivities of maize, ragi, blackgram, horsegram and groundnut were maximum in the sub-region 12.2 (Table 5.27). Overall performance of sub-region 12.1 remained poor compared to other two sub-regions because except rice and maize productivity where it was slightly better than AESR 12.2 and AESR 12.3 respectively, the productivity of all other crops was below the respective average productivities of AER 12.

Table 5.27: Yield of major crops in AER 12

(kg/ha)

Crops	AESR 12.1	AESR 12.2	AESR 12.3	AER 12
Rice	1439	1186	1624	1416
Wheat	1188	1431	1813	1477
Maize	1539	1602	958	1366
Ragi	583	936	691	737
Green Gram	273	397	926	532
Black Gram	342	510	227	359
Horse Gram	312	392	381	361
Seasmum	315	322	381	339
Groundnut	1180	1554	1258	1330
Mustard	328	389	594	437
Potato	8827	10143	13788	10920
Sugarcane	54270	43815	65221	54435

Source: Agricultural Statistics, Department of Agriculture, and Respective State Governments under AER 12, 1998-99.

Cropping system alternatives

It was found that the region has great potential of crop diversification in all types of lands, i.e. uplands, medium lands and low lands both under rainfed and irrigated conditions. However, it requires proper utilization of water resources including rainwater and groundwater. This needs a change in operation of water resource systems and their utilization. For example, the optimum transplanting time for rice is July but transplanting is delayed up to as late as August and even to September as the farmers cannot grow nursery till the canal operation starts in irrigated areas. If groundwater resources are utilized in conjunction with canal water to grow nursery early, the rice crop can be transplanted on time. This will not only improve rice yield but will also help in growing second crop. Alternatively, the practice of "sprouted seed technology" maybe used to get over the problem of 'late transplanting' as appropriate seeds have been developed. In Canal commands, there is possibility of growing crops other than rice, especially in tail-reach of canal during *rabi* season, viz. groundnut, vegetables and pulses. These crops are not only economically better than rice but also involve low duty. However, this requires an improved water distribution network, else the excess water applications to rice will damage these crops.

Summing up

Crop diversification planning for enhancing productivity and cropping intensity

The region has great potential of crop diversification in all types of lands, i.e. up, medium and low lands both under rainfed and irrigated conditions. In canal commands, there is possibility of growing crops other than rice especially in tail reach of canal commands during *rabi* season viz. groundnut, vegetables and pulses. These crops are not only economically better than rice but also involve low input requirements and less water consumption. However, this requires an improved water distribution network else the excess water applications to rice as practised by farmers in the region would continue to endanger water availability to tail-reach farmers in the canal commands and crop productivity. In plateau areas, where the water resources are being created by water harvesting irrigation wells and other water harvesting structures, there is potential of growing vegetables, pulses in post-*kharif* season. There is also a scope of introducing plantation crops with suitable water harvesting measures and application of modern irrigation methods like drip and sprinklers.

Waterlogged area management

In waterlogged areas there are tremendous possibilities of growing Makhana (*Euryale ferox*), Water Chestnut *(Trata bistinosa Roxb.)* and Swam Taru *(Colocasia esculenta)* etc. in place of rice to increase economic productivity of land. Rice-fish integration with proper land modification is another alternative for enhancing productivity of waterlogged areas of AER 12.

VI. Methodological Issues in Future Water - Food Security Analysis

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Introduction

Water is an essential natural resource for sustaining life, environment and food production. Agriculture is the largest user of water, accounting for more than 70% of the total freshwater withdrawals globally and 85 to 95% in India. Availability of water is therefore key to agricultural development. Studies have shown that water-use in agriculture would have to be increased by 15 to 20% during the next 25 years to provide food security for the growing world population (IUCN, 2001). On the other hand, even the current level of water-use by agriculture may not remain sustainable in various regions because of both scarcity and increasing competition for water from other sectors. Currently, 450 million people in 29 countries face water-shortage problems. By 2025, nearly one-third of the world population would face severe water scarcity (IWMI, 1999). Therefore, the water-food scenario in the future is a matter of serious concern. In fact, it would be a great challenge to provide enough water for global food production, especially in regions like Asia and sub-Saharan Africa, where water is already scarce.

In India, the issue currently being addressed is whether agriculture in India will be able to continue supplying adequately to the increasing population, with its limited natural resource-base particularly land and water. There are three reasons for the growing concern: (i) the perceived inadequacy of water to meet the increased food production; (ii) the fast depleting groundwater and pollution of water bodies; and (iii) the fear of increasing conflicts and competitions over sharing of water15. During the last four decades, India has succeeded in achieving a food production level above the population growth rate. Therefore, many projections relying on long-term past trends reached optimistic conclusions. However, the recent trend has led to some discrepancies about the future situation. During the 1990s, the growth rate of agriculture sector began to decelerate, with emergence of problems like degradation of natural resources, stagnation in technical development and slowing down of investment in agriculture (Roy and Pal, 2002). Consequently, discussions about future production potential have been rekindled. So far different professional groups have been addressing two main security issues separately: food security issue is being discussed by social scientists who view it as a distribution challenge; and water security issue is being promulgated by hydrologists who consider it as a technical challenge. However, water is intimately involved with the food security issue. Therefore, it is extremely important to understand the linkages between food and water, while analyzing future water-food security issues. It is imperative to understand the trade-off between various kinds of water-use and the sustainability of water resources.

Concepts of Water-Food Security

The multiple dimensions and interlinked variables associated with water-food security make it difficult to evolve a single indicator to represent the food and water security. Water-food security at regional/country level can be monitored, to some extent, in terms of demand and supply indicators. The concept of food security is interpreted in a variety of ways. However, physical and economic access to food to all the households at all times to ensure healthy and active life, is the crux of food security. In practice, food security is generally equated with the absence of hunger, or at best, provisions of a pre-determined number of calories at the household level. The World Bank has modified this formulation to indicate that food security is 'access by all people at all times to enough food for an active healthy life'.

Water security can be defined in terms of the existing and potential supplies of water in relation to its present and future demands. Because of tightening supply and expanding demand, water security is expected to emerge as a key constraint for future agricultural growth. Water resources are being depleted at a rapid rate, with water tables falling in many parts of the country. Shortage of potable water and agriculture water supplies also affect a sizable population, resulting in unsustainable agriculture and long-term damage to rural livelihoods. As competition for 'limited' water supply increases, responding effectively to these demands is a continuous process requiring comprehensive understanding of the emerging scenario in water sector differentiated by agro-ecological regions.

Within the next decades, fresh-water scarcity will generate strong pressure to use water for food production more effectively. One likely effect would be massive trade in 'virtual water', i.e. food trade induced by water scarcity. Virtual water thus denotes the amount of water needed (but not available) to grow the food, which instead is now imported. In this context, food security is essentially a strategy of buying food instead of growing it, which has superseded the traditional strategy of food self-sufficiency. There are comparatively few countries that have been able to develop this capacity.

Methodology Review

Projections of future demand for and supply of water and food, at national and regional levels are getting increased attention of the scientists, planners and policy makers in the recent years. Several estimates are available, mostly at the aggregate level with simplistic assumptions. The simplest method for projecting future water food scenarios is to extrapolate the past growth trends. However, for obvious reasons, such projection is probably too simplistic, given the complexity in the structure of water and food demand and supply. Further, the static and aggregate approach followed in the past always ignored the agro-climatic and socio-economic variations within and across different regions of India, limiting its usefulness for regional level applications. Therefore, it is better to analyse future water-food security scenarios in an integrated framework involving the following key steps:

- Determining the food requirements based on population, income, calorie intake, and diet composition by urban and rural segments.
- Computing region-specific production of the required food, by crops, using data and estimates of yields and cultivated areas by seasons and production environments.
- Converting the predicted productions into water demands and comparing the irrigation water demand with actual withdrawals in the base year and available renewable water resources.
- Assessing the adverse impacts of increased withdrawals on groundwater balance against projected domestic, industrial and environmental water demands

Food Demand

The demand projections for food items are made keeping in view the past trends in calorie consumption, minimum per capita nutritional requirements, projected population and income growth, and changes in consumption behaviour due to income and price effects of consumption, i.e. corresponding elasticities. Demands for feed, seed and wastages were also considered as decisive factors in determining future demand for agricultural commodities. Further, the demand scenarios are best developed for urban and rural groups separately as consumption behaviour of these two groups differ significantly.

Studies have shown that urbanization, higher economic growth as well as sizeable additions to population would increase the demand for food in India. There is also evidence that the average budget shares for milk and meat are increasing, apparently as a result of structural shifts in consumer preferences. Past estimates for the year 2000 given by National Commission on Agriculture (205 Mt) and the World Bank (191-205 Mt) were not far from realities, even though they were estimated in the 1980s (Kumar, 1998). However, the demand estimates for 2000 (234 Mt) given by Radhakrishna and Ravi (1990) were on a higher side as they used high magnitude of expenditure elasticities. Projected demand (200 Mt) by Samra and Gandhi (1990) are also on the higher side because of double counting of estimation for feed and wastage. Bansil (1996) projected the demand for foodgrains for the year 2000 at 198 Mt, which seems to be on the lower side. This study was based on the incremental approach, providing additional requirements for household and non-household demands over the base year.

Many of the recent projections do not reflect the ground realities, as these do not takes account the regional variations in consumption pattern, shift in dietary pattern, changes in population distribution by income, and changes in taste and preferences. However, a recent study by Kumar (1998) did took account for such deficiencies and projected food-demand supply scenarios for the year 2000, 2010, and 2020 by regions and expenditure classes in rural and urban areas, separately (Table 6.1). The study covered major cereals, pulses, coarse cereals, fruits, vegetables, fish, meat and egg, and milk. In urban areas, the per capita cereal consumption seems to have stabilized at about 135 kg per year, while it has actually declined in rural areas from 185 to 175 kg per capita per year during the last three decades. Diets have also become more diversified with increasing shares of milk, eggs, fruit & vegetables and livestock products.

Table 6.1. Projected food demand-supply scenarios for India in 2020

(Mt)

Food items	Total supply		Total demand		
	TFP growth		GDP growth		
	Constant	Declining	4%	5%	7%
Foodgrains (food & feed)	309	270	293	294	297
Foodgrains (only food)	-	-	264	262	259
Milk	-	-	126	143	183
Fruits	-	-	68	77	98
Vegetables	-	-	136	150	181
Fish	-	-	10	12	18
Meat & Egg	-	-	6	8	12

Source: Kumar (1998)

Food Supply

The food supply projection studies essentially take into account the projected acreage and productivity growth of a crop. But, projections of future food production cannot rely heavily on the past trends, as there is not much scope to increase net sown area in the country, which had gradually increased from 119 M ha in 1950-51 to 140 M ha in 1970-71. There after, the net sown area has been fluctuating between 140 and 142.5 M ha. Any further expansion in irrigated area would be costly, and agriculture would have to compete with industry and urban households for limited water supplies. However, there is enough scope in increasing cropping intensity and yields. The country's performance in agriculture during the last two decades has been reasonably satisfactory. Cropping pattern has witnessed important changes. While the areas under jowar, barley, gram and few other coarse cereals have decreased, the areas under rice, wheat, oilseeds, fruits and vegetables have increased significantly. There appears to be a limited scope for further production gains from the greater use of improved varieties and fertilizers. Resource degradation also could become a significant constraint in future cereal production. Other sources of growth, such as improved crop management or advances in biotechnology, would be required if reasonable rates of increase in cereal production are to be sustained into the future. The National Commission on Integrated Water Resources Development Plan (NCIWRDP) has projected 0.5% increase in cropping intensity every year till 2050 and 50% increase in both rainfed and irrigated yield for foodgrains by 2050 (NCIWRDP, 1999).

Food Demand-Supply

A large number of attempts have been made in the past to find out the demand-supply gap for major food items at several levels. Using 1993 as the base year, Bhalla et al. (1999) have made projections of cereal demand and supply balances to 2020 under alternative scenarios for income growth, consumption behaviour, and agricultural production strategies. While some of the scenarios are based on speculative assumptions, the results show that there are plausible conditions under which India could have cereal deficits of 36 to 64 Mt per year by 2020. If deficits of this magnitude were to materialize, India's cereal needs would have significant impacts on world cereal markets, as well as on the country's trade balance. But, such deficits can be avoided through appropriate agricultural policies. The study by Kumar (1998) has projected surplus cereal supply over demand in 2020 only under constant total factor productivity (TFP) growth scenario. However, with recent trend in the declining TFP, the country is expected to face foodgrains shortages of 20 to 30 Mt (Table 6.1). In another study using United Nations low and high population projections for the country, the total foodgrains requirement for the country has been estimated between 308 to 320 Mt by 2025 (NCIWRDP, 1999). The divergence among all these estimates is mainly due to differences in expenditure elasticities used by these studies.

The Food Security Assessment Model has been widely used to project future food gaps in 67 developing countries, including India (USDA, 2002). In this model, the food security of a country has been evaluated based on the gap between projected food consumption and domestic food availability. The production module for crops has been divided into yield and area response. For other items, it has implicitly assumed that the historical trends in key variables would continue in future. In this model, the food gaps have been calculated using two consumption targets: (i) maintaining base per capita consumption, and (ii) meeting nutritional requirements with international standards. The concept of income-consumption relationship has been used to allocate the projected level of food availability among different income groups. The estimated distribution gap has been used to measure the food needed to raise food consumption of each income quintile to the minimum nutritional requirement. Finally, based on the projected population, the number of people who cannot meet their nutritional requirements has been projected.

A study on China's grain supply and demand has used a framework that includes a supply model for the rice, other grains, and cash crop sectors of the agricultural economy, and demand models have been specified separately for rural and urban consumers for rice, grain, meat, and 6 other animal products (Huang et al., 2001). In addition to income and prices, the model has included a number of structural and policy variables to account for fundamental forces of transformation in China's rapidly reforming and modernizing economy. Supply elasticities have been estimated using the normalized quadratic form of the dynamic dual value function approach. The dynamic duality model has been used because it recognizes that important production factors, such as labour and sown area, while responsive to changes in prices and other exogenous factors, adjust to their equilibrium levels after several years.

Rosegrant et al. (1995) have provided food projections for IFPRI's 2020 vision based on the International Model for Policy Analysis of Commodities and Trade (IMPACT). Projections of global food supply and demand have also been made using an updated version IMPACT model. The model covers 37 countries and regions and 17 commodities, including cereals, roots and tubers, soybeans and meat have specified as a set of country-level supply and demand equations, with each country model linked to the rest of the world through trade. The basic assumption of the global model is that every market be cleared through adjustment in world prices. The model provides a consistent framework for examining the effects of various food policies, investment and productivity, income and population growth on the long-term food demand and supply balances. Food demand is a function of prices, demand elasticities, income and population growth. Growth in commodity production in each country is determined by prices and the rate of productivity growth, which in turn is influenced by advancements in public and private agricultural research and development, extension and education, markets, infrastructure and irrigation.

Econometric models are widely used in many projections. In such models, the relationship among various factors to the food supply and demand is translated into formulae in an econometric way using historical data. The International Food Policy Simulation Model (IFPSIM) consists of a combination of 14 main food commodities, covering the entire world, and is based on simulation modelling. One of the advantages of simulation modelling is that it can generate a number of alternative scenarios. This particular model has predicted the outcome of a wide crop failure. Results show that a wide crop failure would adversely affect (the most) low-income countries. It has also predicted that it might not be possible to increase production continuously or even to keep the current production levels in many countries in future, without sacrificing natural resources.

Water Demand

Projections of demand for and supply of water at national and regional levels have been getting increased attention of the scientists, planners and policy makers in the recent past. Several estimations are available, mostly at the aggregate level with simplistic assumptions about different uses and sources of water. The demand for water is understood as the quantity of water required to be supplied for a specific use. The principal factors affecting water demand are human and animal population and the level of irrigation development, economic growth, urbanization and industrialization. The demand for water can be spilt into several components and in different ways: sector-wise (agriculture, industry, domestic, environmental) or purpose-wise (productive, consumptive). To get a good estimate of the total demand, these classifications are of utmost importance. The projection for irrigation water demand basically depends on irrigated area, cropping pattern, crop evapotranspiration requirements, effective rainfall, soil and water quality, irrigation use-efficiency and conjunctive use of water. It requires extensive hydrological and agro-meteorological data support. Domestic water demand is influenced by per capita consumption of water, population growth and urbanization. Water demand for livestock sector depends upon growth in livestock population and water consumptive use per unit of livestock. Directly or indirectly, the demand for water is related to demand for food, quality of life and need for preserving ecology of a region.

According to Swedish International Water Institute, the minimum per capita water requirement for basic human needs is 100 litre/day (36.5 cubic metres a year). Agriculture, industry and energy usages of water are roughly 5-20 times that of human requirement. Water analysts so far have used the rule of thumb: countries with freshwater resources of 1000 to 1600 cubic metres per capita per year face water stress, with major problems occurring in drought years. Below this threshold, water scarcity will put severe constraints on socio-economic development and environmental sustainability.

The NCIWRDP has prepared estimates of water requirements in India for the years 2010, 2025 and 2050. Based on the review of past studies as well as expert judgments, the estimates were prepared for important uses, and then added up to obtain total water requirements. According to this assessment, total water requirement for the country has been estimated at 717 to 733 BCM (by 2010), 796 to 850 BCM (by 2025), and 934 to 1186 BCM by 2050, depending on the low demand and high demand scenarios.

Taking into account long-term growth in income, industrial development, and expansion of irrigated area, Rosegrant et al. (1997) have projected 35% increase in global water withdrawal by 2020. Much of the projected increase in water demand would occur in the developing countries with fast growing population. Higher rate of industrial growth and increasing trend in urbanization are expected to lead to a larger demand for water.

While estimating demand for water by different sectors, the status of water management, present and emerging water management practices and technologies available globally, and quality aspects of water should also be given due considerations.

Water Supply

Water supply refers to availability of water (both surface and groundwater) for use. The principal sources of water supply in any region are the end products of a number of factors affecting the supply of surface and groundwater and the addition to each through the process of precipitation, evapotranspiration, seepage and consumptive use. As per a recent World Water Development Report, India ranked 133rd among 180 countries in terms of water availability, and 120th in terms of water quality. This clearly demonstrates the alarming situation in India. Though the phenomenon is not uniform across regions, it is sufficiently widespread to cause concern.

The country gets about 420 million hectare-metres (MHM) of precipitation annually, of which 20 MHM is contributed by rivers flowing in from the neighbouring countries. Net evapotranspiration losses are nearly 200 MHM. About 135 MHM is available on the surface and the remaining recharges groundwater. There is little consensus on the issue of exploitable precipitation. Estimates range from 85 to 105 MHM. Even if the lower value of 85 MHM is taken into account, the domestic consumption is not more than 10 MHM, and the remaining goes to irrigation. But, with demand outpacing the exploitable potential, the maximum usable water supply of 105 MHM would be inadequate to meet the growing demand by 2025.

The average annual surface water flow available in the country is estimated at around 1869 BCM. However, because of the topographical, hydrological and other constraints, only 690 BCM of the available surface water can be utilized. The annual renewable groundwater resources are 432 BCM. Thus, the total utilizable water resource in the country is assessed at 1122 BCM. If per capita water availability is any indication, water stress is only just beginning to show. The annual per capita availability of renewable freshwater in the country has fallen from 5277 cubic metres in 1955 to 2464 cubic metres in 1990. Given the projected increase in population by the year 2025, the per capita availability is likely to drop to below the water-scarce threshold level of 1700 cubic metres.

Water Demand-Supply

Recent water models have taken advantages of the development in hydrological science and new technologies like remote sensing, geographical information system (GIS) and geophysical explorations at multiple scales. The development of database and characterizing water resources at regional or national levels have been particularly important in assessing demand-supply gap in water. Several water resources outlooks have also been published in recent years. Margar (1995) has developed a set of global maps, indicating regional variability of water supply and demands. WRI (1998) publishes annually the updated water supply and demand data by country. However, the economic, social and political intricacies are not adequately addressed while assessing physical availability of water resources.

According to a recent estimate, the gap between demand and supply of water in India would be 26.20 MHM by the year 2025, with widespread scarcity, and growing competition and conflicts over the use of water between and within sectors as major fall-outs (Kumar, 2001). In this model, the approach was to estimate the water requirement in India for the period 1990-2025 based on the projected population and economic growth trends and compared it against an estimate of future water supplies. The study argues that solution to the growing water crisis lies in demand management to prevent the financial and environmental risks associated with creating new supplies. The study has also estimated the present utilization of water for various purposes such as drinking, irrigation industry and energy, etc. which is about 750 BCM. The use of water for irrigation currently constitutes about 84% of the water used, which is expected to go down to about 73% by 2025 AD, provided the increasing demand for other uses are met.

An effort has been made to estimate the irrigation water requirements and its available supply in different agro-climatic zones of Punjab so as to arrive at the water balance estimates at two different times (Singh and Sankhayan, 1991). In this study the annual normative demand for water for irrigation purpose has been estimated by multiplying evapotranspiration demand for a crop with the respective area (Table 6.2). After aggregating for all the crops, the aggregate demand was raised by 25% to take care of water requirements for other uses. The results suggested that due to change in cropping pattern in favour of rice-wheat and wheat-cotton, the demand for irrigation water in Punjab was rising fast. In many areas net draft has already crossed the level of annual groundwater recharge and in canal-irrigated area, the requirement is much larger than supply.

Table 6.2. Zone-wise water balance estimates in Punjab

('00 ha-m)

Zone	Total requirement	Utilizable resource	Balance
		1980-81	
I	1179	3544	+2365
II	3552	3641	+88
III	16081	12667	-3414
IV	6907	4506	-2401
V	6842	5095	-1747
Total	34561	29453	-5108
		1989-90	
I	1916	3544	+1628
II	4926	3641	-1285
III	19632	12667	-6965
IV	9215	4506	-4709
V	9202	5095	-4107
Total	44891	29453	-15438

Source: Singh and Sankhayan (1991)

The importance of groundwater in the Indian economy can hardly be overemphasized. With agriculture contributing roughly 27% to India's GDP and production from irrigated land claiming the lion's share, a large percentage of the country's GDP is closely tied to the availability of groundwater. Besides, groundwater is now the source of four-fifths of the domestic water supply in the rural areas, and around half that of urban and industrial areas. Further, in drought years, groundwater is the predominant source of irrigation. While groundwater development has had important implications for the economy, the overuse of groundwater is emerging as a major concern. A burgeoning population is overdrawing aquifers in several states, including Punjab, Haryana, Gujarat, Rajasthan, Andhra Pradesh and Tamil Nadu.

In studies on the future demand-supply for water, the quality issues hitherto received very little attention. Past studies so far have considered water as a homogenous good of potable quality. However, water is used for various purposes, each with its own quality requirement.

Water Food Demand-Supply

There are very few studies that interlink food demand-supply issues with water demand-supply. The International Food Policy Research Institute (IFPRI) has recently analyzed future water scenarios at the global and regional levels through a holistic modeling framework. The model, IMPACT-WATER, explores the impact of technology and management improvement and investment on water productivity, and searches potentials in improving food security through enhancing water productivity. Crop area and yield are specified as a function of beneficial water consumption for crop growth under the condition of crop evapotranspiration requirement, crop and input prices, and investment in agricultural research. IMPACT-WATER allows an exploration of the relationships between water availability and food production at various spatial scales from river basins, countries or regions, to the global level over a 30-year time horizon (e.g. 1995-2025). Water availability is treated as a stochastic variable with observable probability distributions in order to examine the impact of droughts on food supply, demand, and prices. The starting point for the analysis is a baseline scenario that incorporates best estimates of the policy, investment, technological, and behavioural parameters driving the food and water sectors. In the water component, the model utilizes the hydrological data (precipitation, evapotranspiration, and runoff) that recreate the hydrologic regime of 1961-91. Non-irrigation water uses, including domestic, industrial, and livestock are projected to grow rapidly. Total non-irrigation water consumption in the world is projected to increase from 370 BCM in 1995 to 620 BCM in 2025, an increase of 68%. The largest increase of about 85% is projected in developing countries.

The Water Simulation Model (WSM), a joint effort by IFPRI and IWMI simulates water availability for crops accounting for total renewable water, non-agricultural water demand, water supply infrastructure, and economic and environmental policies at river basin level. In this model, crop-specific demand-supply estimates for water were calculated for eight crops - rice, wheat, maize, other coarse grains, soybeans, potato, sweet potato, yam, cassava and other roots and tubers. It incorporates water availability as a stochastic variable with observable probability distributions in food supply, food demand and food prices.

In order to address the problems related to interlinking of food demand-supply scenarios with water scenarios, IWMI has developed a comprehensive water sector model, PODIUM, that integrates food system in a policy interactive dialogue framework for estimating future water-food supply and demand for the year 2025. The model maps the complex relationships between the numerous factors that affect water and food security, and displays information clearly in both graphic and tabular formats. One of the main features of the model is that all major variables and drivers like population growth, calorie intake, changing food habits, water-use efficiency, and crop area and yields are made explicit and can be changed by the users which makes it an excellent tool for scenario testing. It is important to note that PODIUM does not make strict predictions, rather it is designed to explore the technical, social and economic aspects of alternative visions for the future water-food security scenarios.

The computation process in PODIUM is done in three steps: (i) determination of national cereal requirement based on user defined assumption on population growth, calorie consumption, and diet composition; (ii) computation of cereal production using data and estimates on yield and cultivable area under irrigated and rainfed production environments; and (iii) converting the predicted grain production into irrigation water demand and comparing this irrigation water demands with actual withdrawals and available water resources. This is a MS-Excel based planning tool that helps countries to shape their water and food security policies for the coming years. The model predicts increasing water demand for India by 2025 as a result of population growth and changing diet. Annual requirement of fresh water is projected to increase from 870 BCM in 1995 to 1330 BCM in 2025. The share of irrigation water in absolute terms is expected to increase by two-thirds in 2025 over that of 1995 level but in percentage terms, it will decline from 83 to 58% of total water needs during this period due to the increasing competition from other uses.

The PODIUM model is easy to use and understand but it operates at country level, therefore, ignores the substantial heterogeneity within the countries. Statistics in the form of aggregated information at national level sometimes mask issues of local water scarcity. This is especially true when vast spatial and seasonal variations of water supply and demand are present in a country like India.

Need for Disaggregated Analysis

Regional variations are always ignored in demand and supply estimations of both water and food. The static and aggregate approach followed in most of the estimations in water sector in the past have always ignored the agro-climatic and socio-economic variations within and across different regions of India, limiting its usefulness for regional level applications.

Overall, India is a food surplus country, with comfortable buffer stock. However, in spite of current food self-sufficiency at national level, there are regions or pockets which are chronically deficient in food. One may argue in favour of inter-regional movement of foods from food-surplus regions to food-deficient regions. But this can help only in the short-run. Keeping in view the role of agricultural growth in alleviating poverty, it is prudent to produce food within the region itself as most of the food-deficient regions are home to millions of the poor. Further, a region producing sufficient food at present may not be able to produce the same amount in future, due to deteriorating natural resources, mainly water and soil.

Similarly, though India is endowed with sufficient water, there are significant spatio-temporal variations in availability of this resource. At any given time, there are areas of both water excess and water stress in the country. There are significant variations in water availability even within a river basin. For instance, the availability of water within the Ganga basin varies from 740 m^3 in the Yamuna to 3379 m^3 in the Gandhak. Therefore food supply-demand projections need to be appropriately integrated within the modelling framework to simulate and analyze water availability and food production scenarios at the regional levels.

Conclusion

Over the last few decades, modelling water and food systems has received considerable attention globally. However, the models are used at national or global level. What is lacking is regional perspective, i.e. to examine where the situation is bad and to identify the specific areas for action at the disaggregate level. The aggregate macro models generally ignore the substantial differences within the country, particularly for a large country like India.

There is need for a concerted effort to face the challenge of food security in India. Unless planned action is taken at all levels, the chances are that even the early decades of the present century, may not be hunger-free, and malnutrition would continue in the foreseeable future. Since agriculture is highly location-specific, grouping the available land area in the country into different agro-ecological regions based on certain identifiable characteristics becomes all the more important. This may help the country to engage in more rational planning and optimizing resource use for the present and in preserving them for the future. It would be useful to develop an exploratory model as a tool for policy makers, scientists and others to interact and address sustainable water-food security related issues in an integrated framework at national and regional levels.

The County's aquifer level tracking program indicates our sole source aquifer has been depleted by the area's growing population coupled with the water usage mind set of "there is no tomorrow". Several water experts have termed water scarcity in India a 'man made phenomenon' because of short-sighted pricing policy that encourages wasteful use of water and makes it difficult to raise resources for maintenance and expansion of the system. Keeping in view the above scenario, the water resource management in agriculture needs urgent attention as a National Mission Mode Programme.

VII. Workshop Recommendations

The objective of this workshop was to review the progress, finalize methodologies and work plan of the project in order to accomplish the objectives of the project within the timeframe.

A detailed presentation was made on review of methodologies for assessing water and food security at various levels. After critically analyzing the merits and demerits of different approaches and models, the group arrived at the conclusion that the Policy Dialogue Model (PODIUM) developed by the International Water Management Institute (IWMI) be adapted with necessary refinements to address the future water-food security related issues at AER level.

Several issues regarding the temporal and sectoral coverage of the study, functioning of various modules of the model, need and possibilities of refinement in the existing model, and data requirements and their availability were discussed. Major recommendations and the decisions taken at the workshop were:

- Identify deficiencies in the existing PODIUM model and suggest all possible refinements in terms of sectoral coverage, base year, time period, data requirement, and functioning of the model.
- For critically examining the possible refinements, three sub-groups have been formed, one each for the three different modules of the model, namely consumption module, production module, and water balance module. Each group will critically examine the model and will suggest required refinements in the respective module.
- Necessary refinements in the model will be made in two phases. In the first run only those changes will be made which are absolutely necessary. However, in the next run onwards, all possible changes should be incorporated.
- The sectoral coverage will be only on cereal crops in the first run. However, in the subsequent runs, it should also include non-cereal food crops, major livestock products, fish, fruit & vegetables subject to data availability.
- Data will be collected at the district level. It (wherever appropriate), would be aggregated by AESR and AER for model application.

- For calculating the historical trends/growth rates for major variables, TE 1985-TE 1995 period shall be used in the initial runs. However, for final run this should be updated to TE 2000
- The concept and definitions of various variables/parameters/ estimates used in the model should be fine-tuned, wherever required and possible.
- In the first run, the model will use original definitions unless it is going to affect the analysis significantly. For example, the concept of 75% rainfall probability; and the assumption of 10% recycling needs and 25% water demand from non-irrigation sectors to be re-examined in the subsequent runs.

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